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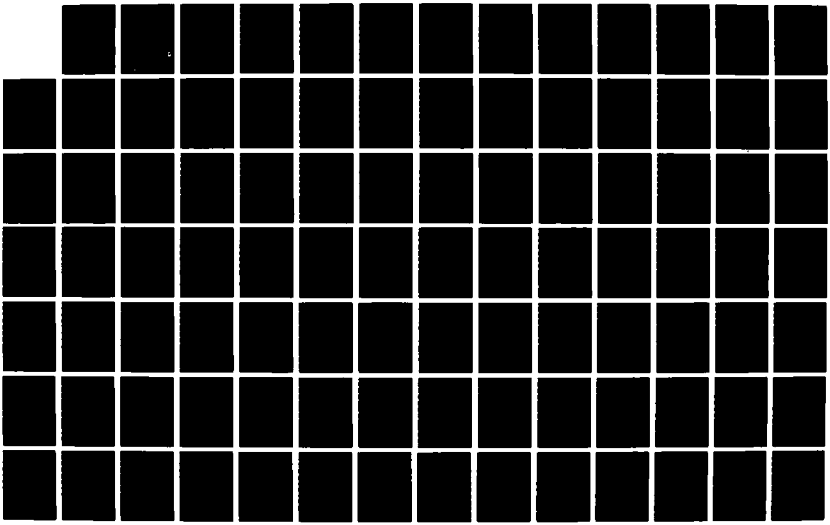

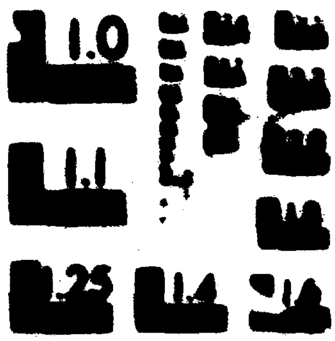
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AND ITS APPLICATION TO
AIR FORCE CIVIL ENGINEERING

THESIS

Richard A. Fryer
Captain, USAF

AFIT/GEM/LSM/87S-7

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Engineering Management

Richard A. Fryer, B.S.

Captain, USAF

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Rich Fryer

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Abstract

This investigation reviewed literature from a variety of sources pertaining to computer-assisted instruction (CAI) for two purposes. The first purpose was to compile information about CAI into a single condensed source for use by Air Force Civil Engineering educational programmers and managers. The second purpose was to examine and present information pertinent to the application of CAI to Air Force Civil Engineering.

The first section introduced such subjects areas as CAI terminology, definitions, instructional methodology choice considerations, courseware development, CAI delivery mechanics, and CAI applications. CAI has been used to provide instruction by means that some have labeled information CAI, drill-and-practice CAI, tutorial CAI, simulation CAI, inquiry CAI, and intelligent CAI.

The next section covered what the literature indicates about the educational impact of CAI. This section presents what the literature has to say about the effects of CAI on student achievement, the effects of CAI on instructional time, the cost-effectiveness of CAI, and the hardware and software tools necessary for the educator who is contemplating CAI lesson development. The literature indicates that CAI results in student achievement at least equal to

that of traditional instruction. Moreover, instructional time has been widely reported to be decreased by the use of CAI, although some experts feel this is mostly a result of the individualized instructional environment which CAI offers students. With regard to the cost effectiveness of CAI, the literature contains few good cost analyses from which conclusions can be drawn.

The final section covered the applications of CAI to Air Force Civil Engineering instructional requirements. Actual reported CAI applications similar to Civil Engineering instructional requirements were presented. Such applications include equipment simulators for training purposes and tutorial and drill and practice for engineering fundamentals review. Additionally, a model of the decision process to adopt CAI as an instructional methodology was formulated. This model provides, in a broad sense, a guide to determine if CAI is the best instructional method to meet given instructional requirements. Finally, a comparison was made of the hardware and software alternatives presently available to the Civil Engineering lesson developer or programmer.

COMPUTER-ASSISTED INSTRUCTION AND ITS APPLICABILITY TO AIR FORCE CIVIL ENGINEERING

I. Introduction

Overview

This chapter presents the purpose and the justification for this research project, introduces the investigative questions, presents the limitations of the study, and specifies the expected objective.

The Purpose of the Study

This research effort reviewed current and past work and literature pertaining to *computer-assisted instruction* (CAI) for two purposes. The first purpose, simply stated, was to compile information about CAI into a single source for reference purposes. The second purpose was to study current CAI technology in order to determine the suitability of CAI to Air Force Civil Engineering.

Background

CAI, as defined in Webster's NewWorld Dictionary of Computer Terms, is

> the use of a computer to provide educational exercises, such as drills, practice sessio..s, and tutorial lessons, for a student: a terminal is used to respond to exercises that have been programmed to assist students at their individual level of ability and speed of learning [13].

Some, such as George Leonard, say "interaction is the absolute essence in learning" (77) and since CAI is, by design, interactive, it clearly has potential in an educational setting. Just what that potential may be for Air Force Civil Engineering will ultimately be decided by trainers, educators, educational programmers, and leaders who have the knowledge of Civil Engineering's requirements and the imagination of how they can be met by CAI. A prerequisite to being able to apply CAI to any requirements is an understanding of CAI.

Justification

The scope of the Civil Engineering training and educational mission is not a small one. In Fiscal Year 1986 (FY86), the AFIT School of Civil Engineering and Services provided instruction to 2,356 students (mostly officers, civilians, and senior NCOs) by way of 105 course offerings. These courses ranged from one to four weeks long and covered 34 diverse topics ranging from Housing Management Applications to Heating, Ventilating, and Air Conditioning Design (3). In FY86, training for the 18 Civil Engineering enlisted specialties was provided by the Sheppard, Chanute, Lowry, and Fort Leonard Wood training sites which trained over 9,100 personnel by way of 95 course offerings in various Civil Engineering technical fields (1). Projections for FY87 estimate technical training quotas to reach nearly 11,000 students (1). The length of this technical training varies from one week (for some of the follow-on specialty courses) to eleven weeks (for some of the basic apprentice level courses) and covers such subjects as plumbing, electrical wiring, production control (managing workforces), and heavy equipment operations (18).

In the private sector, CAI is being used to provide training and aid in undergraduate level education (28). For Air Force Civil Engineering, CAI may hold potential for similar educational applications. For instance, CAI may have a use at the training level for the Base Civil Engineering craftsman, or at the undergraduate level for the Civil Engineering Officer and Senior NCO (non-commissioned officer).

Given the magnitude of Civil Engineering's training and educational requirements, any instructional method that can assist this process deserves serious consideration. To that end, the Air Force Civil Engineering and Services Center (AFESC) is developing a prototype training package to test the application of CAI at the training level (8). When interviewed, the project officers for the above tests expressed a need for a single, comprehensive source of information pertaining to CAI (38, 54). This thesis is meant to fill that requirement and address other issues pertinent to CAI as it may be applied to Air Force Civil Engineering.

In this study, answers to questions about CAI are organized and presented in sequence starting with basic introductory questions and ending with questions about possible Civil Engineering applications. Thus, this thesis should provide a ready reference source or tutorial for those individuals who have a need or desire to become familiar with CAI either for mission reasons or for professional development. Moreover, this work may have utility outside of the Civil Engineering career field to other Air Force specialties investigating the possibilities of CAI.

Research Objectives

As mentioned previously, this research effort set out to gather and present in a logical manner relevant information pertaining to CAI. "Relevant information" is defined here as that information that is useful to the Air Force Civil Engineering trainer, educator, and educational programmer. The end objective was to furnish a document useful to educate those unfamiliar with CAI and provide a ready reference source for those generally familiar with CAI but needing specific information in selected areas.

Investigative Questions

The investigative questions to be answered were placed into th.ee categories: introductory questions, questions about the educational impact of CAI, and questions about the application of CAI to Air Force Civil Engineering. Chapter three contains answers to the introductory questions, which provide the reader with the basics of CAI: what it is and how it is used. Those questions are:

Question 1. What are the various terms, and their definitions, currently used by researchers and experts to discuss the use of computers to provide education or training?

Question 2. What is the process of developing and using computer software to aid education and training?

Question 3. What are the various methodologies of using computers to aid instruction?

Chapter four contains answers to the educational impact questions which provide the reader with insight into the effectiveness of CAI and the tools necessary to use CAI. Those questions are:

Question 4. What does current research indicate about the educational effectiveness of CAI versus traditional classroom instructional methods?

Question 5. What does current research indicate about the cost effectiveness of CAI versus other instructional methods?

Question 6. What general types of computer hardware and software are available to build CAI lessons?

Chapter five contains answers to questions about the application of CAI to Civil Engineering. This chapter provides the reader with an idea of the range of CAI applications available to the Civil Engineering trainer and educator and the effectiveness of some of the tools he or she has to work with. Specifically, those questions are:

Question 7. How has CAI been used by others to meet specific training and educational requirements similar to those of Air Force Civil Engineering?

Question 8. What is the step-by-step process by which a specific Civil Engineering lesson would be evaluated for CAI development?

Question 9. How does the "Wang VS" computer system, being installed in Civil Engineering units as Work Information Management Systems (WIMS), in combination with the software available for it, compare as a CAI device to the "Zenith 248" computer and the software available for it?

Limitations

This study, like any study that deals with computer applications, has several limitations. The first relates to the rapid advances in computer technology and capability. Specifically, anything said herein about the capabilities and cost of a particular computer system is subject to change at any time as manufacturers improve and upgrade their products and adjust their prices. The second limitation relates to question seven regarding the application of CAI to Civil Engineering. The researcher acknowledges that the applications identified are not all encompassing. Some applications similar to the requirements of Civil Engineering may not have been included either because they were unpublished or published in obscure journals or are presently under development. Hence, portions of this research should be read keeping current computer capabilities and applications in mind.

II. Methodology

Overview

The purpose of this chapter is to describe the conduct of this research effort and to outline the steps taken to gather the information presented in this thesis.

Investigative Questions

The investigative questions, required to be answered to provide a document capable of meeting the objective of being an introduction to CAI and a reference source, range from the simplest what-is-it type of question to the more specific how-can-we-use-it-in-Civil-Engineering type of question. Nine investigative questions were formulated and grouped into three sections: introductory questions, questions about the educational impact of CAI, and questions about specific Civil Engineering applications. These questions were presented in chapter one.

Methodology

Since the goal of this thesis was to investigate past and present work and writings about CAI, the logical method of conducting this effort was through a comprehensive review of reports, trade journal articles, professional journal articles, and books on the subject. Dominowski recommends using the following principle to conduct a literature search: "Work from the general to the specific . . . and work backwards over time" (19:326). Dominowski goes on to expound on this by stating "Begin your search with the most recently published sources, you can [then] use the references contained in those sources to lead you to earlier sources" (19:326). This methodology was used to a great extent in the conduct of this research effort. In addition to printed matter, interviews were used to gather some of the information presented in this thesis. Much of the information about hardware capability and software availability for specific Civil Engineering uses came from telephone conversations with knowledgable technicians and experts.

Index searches were conducted at the Air Force Institute of Technology, Wright State University, and the University of Dayton using:

1. The Air University Library Index
2. The Air University Abstracts of Research Reports
3. Reader's Guide to Periodical Literature
4. The ACM Guide to Computing Literature
5. The Humanities Index
6. The Social Sciences Index
7. The Business Periodicals Index

CAI-related articles were found under such reference headings as Computer-Aided Instruction, Computers-Educational Uses, and Computers-Training.

Additionally, computer indexing services, such as that provided by Defense Technical Information Center (DTIC) and DIALOG, were used to provide additional sources of information. Keywords for such searches included "Computer-Assisted Instruction" and "Computers-Education Uses".

Moreover, the ERIC (Educational Resources Information Center) document section of the University of Dayton provided access to many documents that would otherwise be difficult to obtain.

Not all questions could be answered by the literature. Question seven, how has CAI been used by others to meet specific training and educational requirements similar to those of Air Force Civil Engineering, required the identification of Civil Engineering's education and training requirement prior to a literature review. This was accomplished through a review of Civil Engineering regulations and policy letters, and by interviews with those within Civil Engineering responsible for education and training functions. Interviews were conducted with the training officers at the AFESC and with the Dean of the AFIT School of Civil Engineering and Services. Once identified, these requirements were matched with CAI applications found in the private sector or other areas of the government.

Additionally, question nine, regarding the comparison of the Wang VS system and the Zenith 248 as CAI systems, required the use of information from question six, which resulted in identification of types of hardware and software available to build CAI lessons. Specifically, these two systems were compared on: memory, input options, software availability, software capability, interactive video support capability, color capability, and costs.

III. Introduction to CAI

Overview

The purpose of this chapter is to present and examine current and relevant literature relating to the first three investigative questions concerning what might be called basic questions about CAI: simply put, what is CAI, how is it used, and what forms can it take? These questions are answered in sequence.

Question 1

What are the various terms, and their definitions, currently used by researchers and experts to discuss the use of computers to provide education or training?

Part of the problem with trying to discuss CAI is figuring out how CAI differs from other terms used by those speaking about the use of computers to provide or enhance education. Such terms as CBT (computer-based training) and CBI (computer-based instruction) tend to confuse the issue. The answer to this question provides the terminology and definitions associated with computers in education.

Terminology. Despite 25 years of ongoing research on the use of computers to provide education or training, the terms used to describe this subject still vary greatly. Parry, Thorkildsen, Biery, and MacFarlane (Parry et al.) state that "computer-based instruction" (CBI) was the most appropriate, generic term to describe this subject, which has also been called "computer-based teaching", "computer-augmented instruction", "computer-based learning", "computer-based training", "computer-based instruction" and "computer-enriched instruction" (64).

However, the consensus among the researchers and other experts in the field weighs heavily against their choice. While others (33, 73) prefer the term "computer-based training" to describe the use of a computer in an instructional setting, the favorite by far is "computer-assisted instruction" (20, 21, 36, 46, 51, 74, and 83).

This fact is not surprising since the term computer-assisted instruction best describes the process that all the researchers were studying: the use of <u>computers</u> as an educational tool to <u>assist</u> and enhance the <u>instructional</u> process. "Computer-based instruction" appears flawed as it leaves the impression that computers form the <u>basis</u> or heart of instruction, a concept which even Parry et al. shun by stressing that "highly touted innovations... don't lessen the teacher's role" (64:32). Moreover, computer-assisted instruction has taken hold as a keyword in many publication indexes and in automated literature search services such as DTIC.

Besides computer-assisted instruction and the various other terms presented, there is one additional term worth mentioning. Computer-managed instruction (CMI) involves the use of the computer by the instructor to perform the administrative and management tasks associated with teaching. This use includes keeping track of assignments, grades, and other management statistics and scheduling lessons, make-up sessions, and quizzes. Some researchers think of computer-managed instruction as a term for the broader application of computers in education in general, with computer-assisted instruction only a subset of computer-managed instruction. Others think of computer-managed instruction and computer-assisted instruction as subsets of something larger which some call computer-based training and others call computer-based instruction.

Definitions. There seems to exist almost as many definitions of CAI as there are authors. Perhaps the definition provided by Webster's NewWorld Dictionary of Computer Terms is a good starting point. The dictionary defines CAI as

> the use of a computer to provide educational exercises, such as drills, practice sessions, and tutorial lessons, for a student: a terminal is used to respond to exercises that have been programmed to assist students at their individual level of ability and speed of learning [13].

This is a somewhat simplified and limited definition of CAI. For instance, it omits the use of simulations as a CAI methodology. However, it does convey the basic idea, the use of computers to aid the educational process. Another definition is provided by Kemner-Richardson, Lamos, and West. Their definition is less specific but does not limit the possible applications. Specifically, they define CAI as:

> The use of the communication and storage capabilities of a computer to provide the direct presentation of instructional materials and/or provision of practice to the learner [46:9].

For the purposes of this research, CAI and CMI were thought of as distinct, though interfacing, applications of a computer in education. CAI was used to describe the instructional application of computers and CMI was used to describe the managerial application of computers in education. The specific operating definition of CAI used throughout this study was the latter one presented above. Other related terms and their definitions are compiled and presented in Appendix A.

<u>Question 2</u>

What is the process of developing and using computer software to aid education and training?

To answer this question, the researcher examined three processes: the process leading to the choice of CAI as an instructional methodology, the process of courseware development, and the process of the delivery of a generic CAI lesson. These are outlined below.

<u>Choosing an Instructional Methodology</u>. The process of choosing an instructional methodology to satisfy a particular training or educational requirement involves a number of considerations which include: identifying organizational needs, instructional capabilities needed, sufficiency and availability of existing courses inside and outside of the organization, assessment of support and resistance to any

particular method of instruction, and cost analysis of the various instructional methods that would adequately meet the requirements (17).

An organization may not desire the student to learn in an individualized environment such as that offered by CAI. Some organizations, like the military, may want the student to not only master the lesson material, but they may want the student to be exposed to "values and attitudes, such as professional ethics" that can not be attained easily by way of CAI (46:16).

Another factor influencing the choice of an instructional methodology is the subject material itself. "The choice of CAI should be driven by instructional need for that medium's unique capabilities" (46:17). CAI should be thought of as one method out of many that may satisfy an instructional requirement. Thus, "CAI should be chosen based on its potential for best meeting instructional or institutional needs" (46:17).

The use of an existing, available course to satisfy an instructional requirement would seem to be the best alternative to meet that need. Indeed, AFM 50-2, Instructional Systems Development, specifies that the educational planner should investigate this avenue before pursuing the development of a new course (17). However, this advice does not preclude the investigation and evaluation of CAI or any other method to satisfy the requirement. It may turn out that the existing course is not the best alternative from a qualitative point of view. Another method may be better suited for the new requirement than the method used by the existing course. Moreover, despite the up-front costs associated with developing a new lesson using an alternative methodology, the net cost may be cheaper when amortized over the expected useful life of the lesson.

Courseware Development. The CAI courseware development process follows the same general pattern as the development process of any instructional lesson. This process, commonly called the instructional systems development (ISD) process, involves "the deliberate and orderly process for analyzing, planning, developing, and managing the instructional program" (27:9).

There is not a universally accepted model of the ISD process. Some outline an eight step process to achieve lesson development (4:275). AFM 50-2 outlines a six step model of the ISD process (17). The Air Force Institute of Technology modified the training-oriented Air Force ISD process to produce an education-oriented process called the Academic Instructional System (AIS) (2:2). AIS's basic approach is the seven-step process outlined as follows: (1) identify system educational requirements, (2) define educational requirements and identify student input, (3) plan and develop the instruction, (4) develop a syllabus, (5) provide adaptive instruction, (6) evaluate instruction, and (7) revise/review each of the steps above (2).

A simple yet encompassing model, based on the Air Force

ISD model for curriculum design, is offered by the 436th Strategic Training Squadron (STS). The squadron outlines five major steps which are the analysis step, the design step, the development process, the validation step, and the evaluation step (27). Figure 1 is a representation of this model.

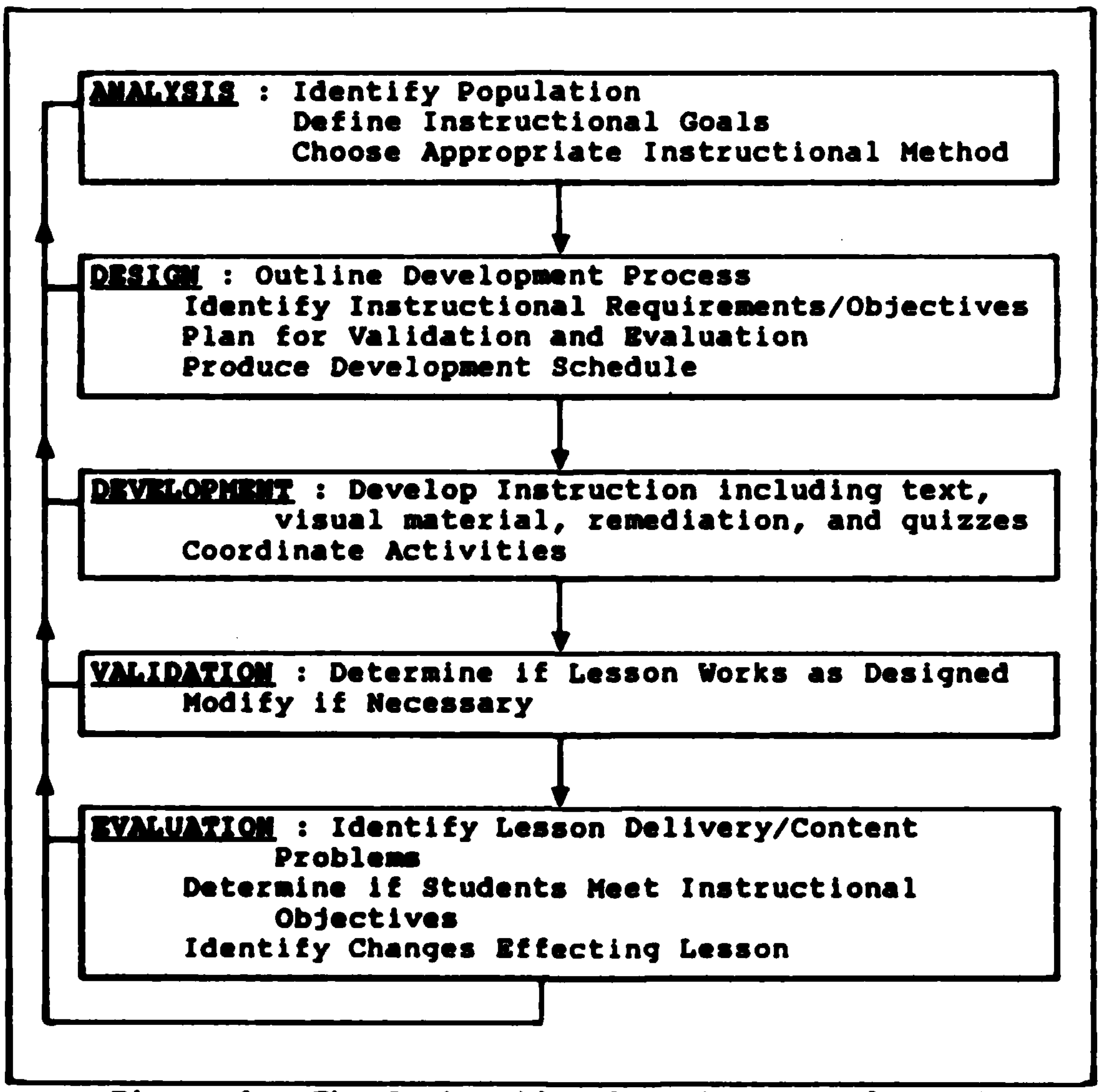

Figure 1. The Instructional Systems Development Process (27)

The analysis step involves identifying the target population requiring the instruction, identifying characteristics of that population (such as age, educational background, and experience), defining the instructional goals, determining the instructional methods/media, and setting milestones for the remainder of the ISD process. Analysis is that first step "essential for establishing the direction of the actual training program" (27:9). It is in the analysis step that CAI would be chosen or rejected as an appropriate instructional methodology. That decision is examined more closely in chapter five.

Following the analysis step is the design step. Design involves the mapping of the development process that will be presented next. The 436th STS lists the following as end products of the design process: instructional requirements, instructional objective, task listing, plans for validation and evaluation of the lesson, and an updated development schedule with milestones. Also, in this step the lesson sequence would be developed based on the above products. If CAI is the chosen methodology, then an appropriate design for branching the instruction would also be developed.

The next step "is a monumental task for the CDM [course development manager] and consumes the majority of the ISD effort" (27:10). This development step consists primarily of the actual building of the lesson itself. This effort involves the coordination of other subject matter experts, assistants such as typists, and media experts (photographers, for example). The quality of the end product "depends primarily on how well the analysis and design steps were accomplished" (27:10). Estimates of the amount of the lesson preparer's time necessary to develop a one-hour lesson range from 25 to 300 hours (46:147), with the majority of the experts estimating in excess of 100 hours (29, 46). For CAI this step entails text and graphics development and lesson branching development.

The next step, validation, involves testing the lesson to see if it meets its designed instructional objective. Validation is a necessary step to be "certain that the instruction works" (27:11). This step includes coordinating operational tryouts (pilot studies), analyzing validation data, and revising the lesson. Validation may cause some lesson modification to overcome stortfalls or deficiencies in the lesson.

The final step, evaluation, involves both internal and external evaluation. Internal evaluation is performed by students and instructors on the lesson itself and identifies lesson delivery and content problems. External evaluation "determines whether the course graduates can perform" and identifies changes in the instructional requirements (job changes, process changes) that affect the lesson (27:13-14). Evaluation is a continuing process which provides feedback for continuous lesson updates.

<u>Problems to Avoid</u>. Several warnings bear mentioning at this point. First, a problem to be avoided by

the educator preparing CAI lessons is that the computer is an expensive 'book' if used as such. If the subject material does not need or cannot incorporate interactivity into its design, then that lesson is no better than a book or handout. As Cartwright said, "Page turner CAI (as this misuse of a computer is dubbed), even with color and graphics, is still a poor use of the computer" (12:168). Page-Turner CAI "is best left [for the] book; the pages are cheaper and easier to turn" (67:27). Interactivity, then, is the key to CAI. As Gery says "we need to design programs with interactivity as the core" (30:C8). Many of today's CAI programs deliver text with "interactivity thrown in as an afterthought...; people's tolerance for that is low" (30:C8).

Another warning mentioned by some experts concerns student control over exiting the lesson. Stephenson advises that it "is very important in writing [CAI lessons] that the student must be made to feel he or she is in complete control at all times" (75:11). He suggests that an escape, exit, or 'bailout' option be available to a student at any time.

Finally, as mentioned earlier, CAI must be designed to be interactive. To that end, courseware development should allow for frequent questioning and quizzing of students (4:92). This not only keeps the student involved in the instruction, but it provides that necessary immediate feedback to the student about his or her performance (4:114).

Mechanics of CAI Delivery. The process of using a CAI program to deliver instruction follows the outline below. After the student sits down at the computer terminal and follows the logon or boot procedures for the particular computer, the student loads the CAI lesson or program into the machine and runs it. The student selects which module he/she wishes to receive. The computer presents the module to the student, stopping at predetermined points for input from the student. The student's responses may cause the computer to present the previous material in a different manner if those responses indicated that the subject material was not fully comprehended. If, however, the student's responses indicated that all the lesson material had been assimilated, the program may accelerate the pace of instruction to prevent boring the student. The pace would return to normal once the student's responses indicated the lesson material was challenging.

This process would continue until the student either completed the lesson or ended the session. In either case, a CAI program should, as a minimum, summarize the session for the student, indicating such things as time on the machine or total CPU time (for time-sharing systems), score for the session, and the student's weak and strong areas. Additionally, if the student did not complete the lesson, the program should store the last point the student worked at to enable the student to resume at that point when he or she returns to the lesson (16, 61:101).

Additionally, through what may be termed a CMI interface, the instructor would also have information about the student's performance and strengths and weaknesses. The instructor may use this information to work one-on-one with a student struggling in some area.

Question 1.

What are the various methodologies of using computers to aid instruction?

CAI Applications. Some writers divide the educational use of computers into three categories; tool, tutor, and teacher (67:6). Others would add tester to that list (4, 43). Alessi and Trollip identify ten methods of using CAI: tutorial instruction, drills, simulations, instructional games, tests, problem-solving environments, teaching tools, games, intelligent CAI and computer-controlled video (4:52-56). However, it would appear that several of these are subsets of others. In their handbook for Air Force Instructional Managers, Kemner-Richardson, Lamos, and West recognize six forms that CAI can take: Informational, Drill-and-Practice, Tutorial, Simulation, Inquiry, and Intelligent (46:19-24). In all these applications the basic functions that CAI serves, however, have remained the same: "the presentation of information, the demonstration of the applications of skills and knowledge through examples, and the opportunity for practice" (46:19). Kemner-Richardson et al's view of the applications of CAI appeared more complete than that mentioned earlier in that they specifically took into account drill-and-practice and simulation CAI commonly listed by many experts. Thus, this researcher presents their model of the various forms of CAI.

Informational CAI. Informational CAI is the use of the computer to provide information to support instruction. That instruction could take the form of conventional classroom instruction or other methods such as tutorial CAI. Generally in Informational CAI, the computer can be thought of as a database containing pertinent subject information, text, graphics, and other forms of information. This information would be available to the student for reference, for problem solving, or for help related to material presented in class. This form of CAI "can be used as a dynamic tool, with information such as helpful hints or lessons learned added by instructors at any time" (46:19) or any point in the database.

Drill-and-Practice CAI. Drill-and-Practice CAI is the use of the computer to provide reinforcement of material presented by other means of instruction. Eisele believes that drill and practice probably constituted the first application of CAI. He states that besides mathematical applications, "early drill and practice applications included spelling practice, word recognition, and memorization of factual information" (24:15). Drill and practice have not changed much in basic form since then. The program "drills students on parts of a process; e.g. what do you do after you have installed the condenser" or "quizzes students on nomenclature (e.g., parts of anatomy, parts of a vehicle)" (46:21). The general structure and flow of drill-and-practice lessons is presented in Figure 2.

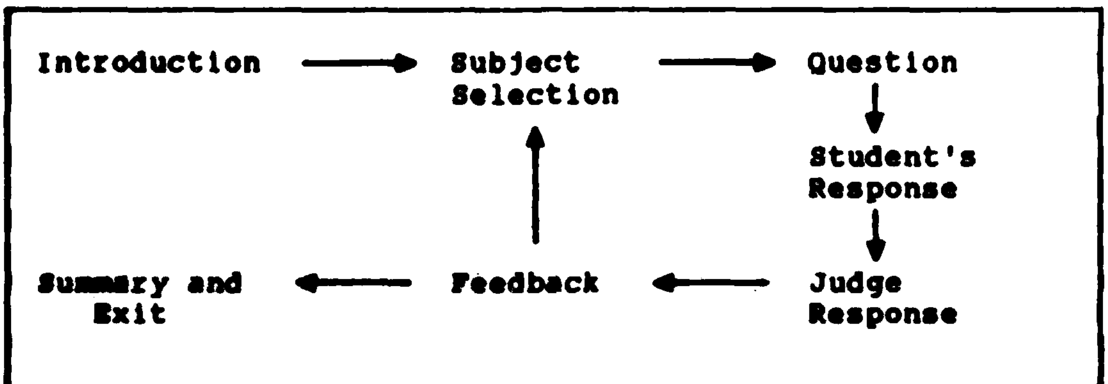

Figure 2. General Structure and Flow of Drill-and-Practice Lessons (4:135)

Drill and Practice is an important part of any learning process and hence this capability is not to be taken lightly. Kemner-Richardson et al. speak of the importance in these terms:

> Practice not only verifies that the learner can actively use concepts, skills, and procedures which have been taught , it also affords the learner the opportunity to practice transferring and generalizing concepts and strategies to problems dissimilar from examples demonstrated (46:21).

The computer is well suited to this task, being able to quiz and provide immediate feedback to the student.

Tutorial CAI. The previous two forms of CAI were supplemental to classroom instruction or other forms of instructions. Tutorial CAI is the first form of CAI discussed that uses the computer to present instruction complete by itself without the use of conventional classroom instruction or other non-computer methods. Clearly, tutorial CAI is the first level of CAI at which there are stand-alone capabilities, meaning that instruction can be solely presented by interaction with the computer. Tutorial CAI is described as

> frames of text and graphics . . . typically interspersed with embedded questions such as constructed answer, true/false, multiple-choice, or matching questions. Immediate feedback messages and schemes (including branching to remediation or elaboration segments) are, in good measure, what makes the lesson a tutoring experience" (46:21).

Alessi and Trollip say that effective tutorials strive to present information or model skills and guide the student through an initial use of the information or skills (4:65-66). Tutorials "usually do not engage in extended practice or assessment of learning; . . . extended practice and assessment are the domain of other methodologies" (4:65). These other methodologies are drill-and-practice and testing applications of CAI. Figure 3 presents a model of the general structure and flow of a CAI tutorial.

There are some cautions to be observed in preparing or purchasing tutorials. Care must be taken to ensure that tutorials do not become "linear, not highly interactive, nonadaptive, and . . . take a view of the learner as a

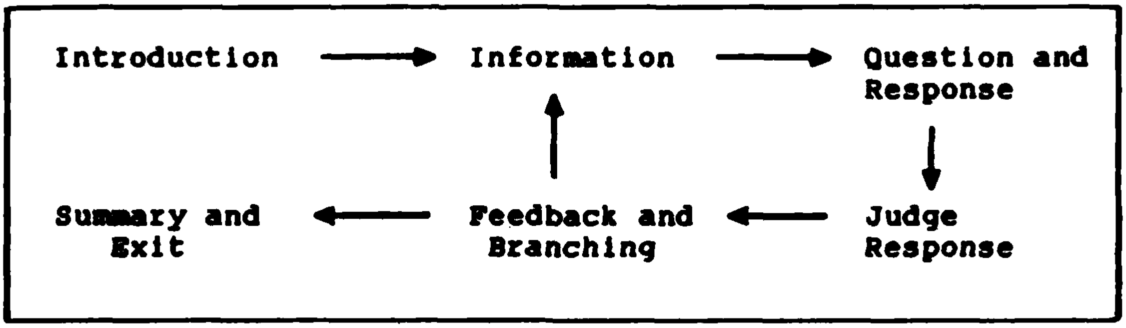

Figure 3. General Structure and Flow of a Tutorial Lesson (4:66)

passive recipient of information" (46:22). The Naval Postgraduate School uses computer tutorials to "train or retrain students in the use of (IBM and VAX) computer systems on campus" (67:7).

Tutorials can be used to provide instruction in virtually any area of study ranging from the humanities to the social and physical sciences (4). "They are appropriate for presenting factual information, for learning rules and principles, or for learning problem-solving strategies" (4:65).

Simulation CAI. Simulation CAI is the use of the computer to model a specific situation or process which places the student into that situation or controlling that process. Eisele says "Simulations take the form of presenting a situation to the learner, and requiring a response based upon a decision of how to act in that situation, with feedback in the form of the likely consequences of having acted in the way decided upon"

(24:15). "Simulations usually operate in cycles. Each cycle begins with a simulation in a given state" (46:22). The student is then given alternative courses of action from which he or she makes a choice. This choice then determines the state of the simulation or process in the next cycle. Simulations can either "faithfully mimic" a situation or process or they can interact "with the student, coaching him or her and providing feedback on the effectiveness or advisability of actions taken" (46:22). The general structure and flow of a simulation is presented in Figure 4.

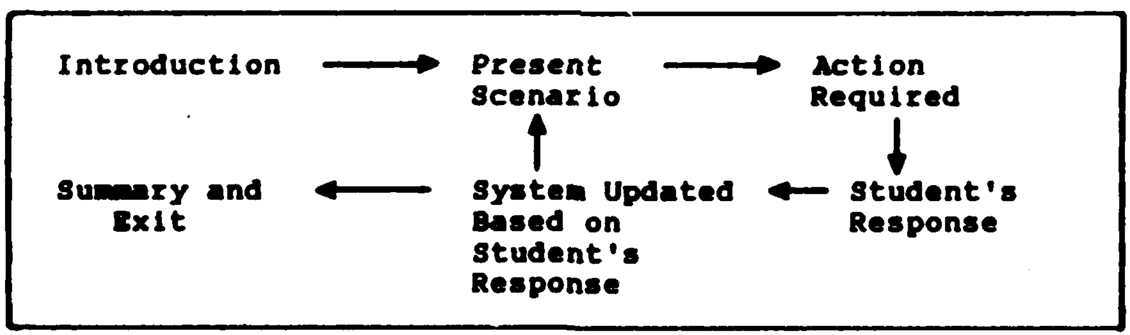

Figure 4. General Structure and Flow of a Simulation (4)

Simulations can be run directly from a computer and its display, they can operate in conjunction with other devices or computers specifically designed to mimic a process, they can operate actual mock-up operating equipment set in a test situation (73). Stammers and Morrisroe call these last applications, which tie additional devices into the CAI computer controlling the lesson, "adjunct training" (73).

Simulations are familiar to many "having been employed for training medical personnel in patient care, for teaching some aspects of economics, ecology, genetics, and history, and for training pilots" (24:15). Some experts believe simulations are an improvement over tutorials and drill-and-practice from a motivational standpoint since the student is active throughout the learning process (4:172).

Inquiry CAI. Inquiry CAI combines some of the features of Information, Drill-and-Practice, and Tutorial CAI. However, with Inquiry CAI, the student controls the subject, length, and breadth of instruction. "Inquiry (CAI) allows the student to get to what it is he or she needs or wants to learn" (46:23). The student may choose to simply practice some exercises pertaining to a specific subject or receive instruction on that subject. Inquiry CAI is "especially appropriate to those who need refresher or brush-up training in very specific areas" (46:24).

Intelligent CAI. Intelligent CAI is the use of the computer to "emulate the one-on-one interaction of an instructional dialogue" (46:24). Some, such as Enger et al., claim that the "computer is very inflexible and thus cannot usually react to a student's unexpected question. Computers inherently have trouble helping students develop 'synthesis' and 'analysis' skills" (25:140). Intelligent

CAI is an application under development which addresses this problem.

Intelligent CAI is a combination of CAI and the use of Artificial Intelligence techniques to provide "Socratic dialogues or meaningful coaching" (46:24) for the student. The objective is to approximate the human student-teacher interaction where the teacher is a subject-matter expert, knows or determines what the student's present level of understanding is vis-a-vis the subject, and knows how to present the subject to the student in a manner that facilitates understanding. Intelligent CAI as yet does not exist, but is considered to be the future form of CAI (46).

Summary

This review of current literature on the subject of computer-assisted instruction (CAI) provides answers to the three introductory investigative questions.

The answer to question one discussed the problems with the lack of a specific, universally accepted term to describe the use of computers to aid instruction. Additionally, a definition of CAI, the term chosen by this researcher, was presented.

The answer to the second question provided an insight into how CAI is developed and used.

The answer to the third question presented six forms of CAI: informational, drill and practice, tutorial, inquiry, simulation, and intelligent CAI.

IV. Educational Impact of CAI

Overview

This chapter will provide the reader with insight into questions related to the educational effectiveness of CAI, the cost effectiveness of CAI, and the tools necessary to implement CAI in an educational or training setting. The fourth, fifth, and sixth investigative questions presented in the methodology are answered in sequence.

Question 4

What does current research indicate about the educational effectiveness of CAI versus traditional classroom instructional methods?

To answer this question we must look at two aspects of what one may define as effectiveness. The first of these is qualitative. Normally, a measure such as student achievement on some standard test instrument is used to judge the qualitative effectiveness of a teaching method (28). Secondly, CAI must be judged on its quantitative effectiveness. To measure quantitative effectiveness, the study examined the effect of CAI on the time it takes to present the material to a student and have the student attain the desired learning level.

CAI Effect on Student Achievement. The qualitative success of any educational process, tool, or method is judged by the success it has on student educational achievement. Any method or tool that does not result in student achievement equal to existing methods is of questionable value to the educator. Hence, part of the research on CAI has focused on the effectiveness of CAI as measured by student achievement.

Some educators are skeptical about the value of CAI. Hanley warns that CAI is a novelty and as such has inherent motivational properties that will wear off as soon as the novelty effect is gone (36:36). Palozola says, somewhat tongue in cheek:

> What's wrong with (CAI)? In a word, its boring. The key to learning-motivation, which often is boosted by the instructor-is missing entirely. Multiple-choice branching . . . is monotonous . . .these innovations tend to be one big yawn for trainees used to the marvels of television, cinema and video arcade games [62].

However, Hanley summarized the results of a meta-analysis review of 48 such studies by stating, "students who had received CAI outperformed students who had received only conventional instruction in 81% (39) of the cases" (36:26). Other researchers also confirmed higher achievement using CAI. Wilkensen and Chattin-McNichols used CAI to train police officers on the effects of a Supreme Court decision on an existing law. They demonstrated that CAI resulted in 20% better officer understanding of a specific law change versus traditional department training methods (83). Valuk reported on the use of CAI in an elementary school to improve student math skills. While his results are not quantified, he reports that CAI students have demonstrated better performance (76). _Management Review_ reporters interviewed educators at the Catholic University of America and found that "students . . . can learn spelling faster and more easily by using computers because" they are not hampered by the "mechanical difficulties posed by writing manually" (9).

Increased performance from the use of CAI was also noted by researchers at the Air Force Academy. Enger et al. reported an experiment conducted using two student groups, each "reasonably similar in ability," one of which accomplished its homework assignments via a computerized drill-and-practice program and the other by conventional methods. The group that used the CAI drill-and-practice routine "did nearly twice as well as the other group" when tested on the lesson subject matter (25:137-38).

Other researchers have concluded that CAI is equally as effective as traditional classroom instruction (20, 21, 28, 43, 51, 64). Dossett and Konczak concluded quite plainly that "CAI is _at least_ as effective as conventional classroom or programmed instruction" (20:44). Additionally, Lepper, attempting to stimulate debate on CAI, writes about qualities of CAI as compared with traditional instruction. He credits CAI with being not only equal to traditional instruction in many respects, but with additional capabilities such as providing immediate feedback, providing types of feedback not normally available in the classroom, and providing highly specialized individual training (51). Moreover, Dossett and Hulvershorn conducted a study using CAI on Air Force trainees in technical training school. They reconfirmed earlier studies proving the results of CAI delivered instruction to be statistically equal to the results of traditional classroom instruction from a student achievement point of view. They also showed CAI was a much faster method (21). Additionally, Parry et al. mentioned several efforts they examined that demonstrated CAI produces "student achievement about equal to that achieved with traditional instruction" (64:33). Another researcher, Gerardo, conducted an experiment that demonstrated that CAI, in conjunction with traditional classroom training, results in improved student performance (28). Specifically, he concluded that "student learning in a FORTRAN course delivered in the traditional lecture mode is significantly increased when supplementary CAI resources are made available" (28).

Burns and Bozeman conducted a meta-analysis of studies of CAI effectiveness in the mathematics curriculum area (7). They concluded that

> The analysis and synthesis of many studies do point to a significant enhancement of learning in instructional environments supported by CAI, at least in one curriculum area - mathematics (7:37).

Perhaps the most comprehensive study of this area was performed by Kulik, Kulik, and Schwalb (Kulik et al.). They performed a meta-analysis of 25 studies of CAI applied in the area of adult education over a wide range of subject areas (48). Their results indicated that CAI "raised final examination scores in the typical study by 0.42 standard deviations, or from the 50th to the 66th percentile" (48:248). These results were similar to results they had found earlier when performing meta-analysis on studies performed at the elementary, secondary, and college levels (48:248).

Some of the differences between the results of the studies mentioned earlier concerning CAI's instructional effectiveness, may be due in part to the way the study was conducted. Johnson, Johnson, and Stanne (Johnson et al.) demonstrated that the learning environment under which the instruction is given impacts the effectiveness of CAI. Students subjected to CAI under what Johnson et al. term "cooperative learning" (conditions where students' achievement is based in part on the achievement of the group as a whole so that competition within the group is minimized) outperform students who work individually or in groups where members compete amongst themselves (45). The implication of this finding is evident with regard to instructional development. The conditions created by the developer impact the effectiveness of the CAI lesson developed. Moreover, this may explain why some of the studies showed greater achievement than others.

Thus, the evidence to date establishes that CAI produces results at least as effective as, and in some cases more effective than, traditional classroom instruction.

CAI Effects on Instruction Time. The second, or quantitative, aspect of CAI is its effect on length of instruction time. This perspective is important because it is not enough to demonstrate that a new educational tool or method is successful only by the criterion of student achievement. An educational tool or method must also provide the expected level of student achievement in _an acceptable amount of time_. For example, a new teaching tool that equals traditional classroom student achievement levels, but only after an instructional period twice as long as traditional classroom instruction, is of little practical benefit since it is essentially half as efficient as traditional classroom instruction. Thus, research has also focused on the effects of CAI on length of instruction. Indeed, "the need to decrease training time while maintaining, and even improving mastery of the subject matter is becoming the focus of management's attention" (57:12). Gordon and Lee suggest that the use of CAI could cut down a normally five-day meeting to a three-day meeting (33).

Past and recent research bears out their suggestion that CAI actually reduces instructional time and provides equal levels of student achievement. In 1967, Grubb reported that "W. Uttal, investigating the effects of special terminals connected to an IBM 650 system, found that at the end of 50 hours of stenotype instruction at the terminal, college students were performing at a level equivalent to people exposed to 200-300 hours of conventional instruction" (29:77). More recent research by Parry et al. on seven studies of CAI demonstrated that CAI reduced length of instructional and/or learning time over conventional class-room instruction time (64:32-34). These results were convincingly validated by experiments by Dossett and Hulvershorn. They demonstrated that CAI produced a 37% reduction in training time over conventional training methods for Air Force personnel in a technical training program (21:553-555).

Kulik et al. found as a result of their meta-analysis of CAI adult education studies that "In twelve of the thirteen studies reporting instructional time, the computer did its job quickly"--on the average about a 29% reduction in instructional time over conventional teaching methods (48:249).

Dossett and Hulvershorn also recognized that many schools and universities could not afford to purchase sufficient computer terminals for individual student use. Therefore, they decided to conduct another experiment to see if there would be any detrimental effect to pairing students at a terminal. They discovered that student pairing had a synergistic effect and actually resulted in an even greater reduction (49%) in training time (21:555-557). Additional evidence to support this finding comes from an earlier study by Grubb. He reported that "the effect of pairing high (performing) students in the study had little effect on immediate error rates (the measurement of performance) within the course as measured by their controls. With low (performing) students, however, the pairing arrangement reduced immediate error rates twenty five to fifty percent (25-50%) over their controls" (29:77).

With regards to retention of knowledge, very little research has been reported. One study of the effectiveness of CAI to provide foreign language instruction tested students some time after their lesson was completed. The results indicated that the students who received the CAI treatment still out-achieved their counterparts who had received the control lesson (language tapes)(44). Kulik et al. recommended that "future evaluations of adult [CAI] might therefore pay more attention to such areas" (48:249).

Thus, the weight of evidence clearly establishes that CAI can reduce instruction time over conventional classroom instruction (20, 21, 29, 44, 48, 64). The obvious benefits from this are cost savings. As Dossett and Konczak concluded, "shorter training times . . . . translate directly into increased efficiency; training costs are lower and a greater number of graduates qualify for work assignments in a shorter period of time" (20:44).

Question 5

What does current research indicate about the cost effectiveness of CAI versus other instructional methods?

In 1967, some estimates of the cost of CAI where as high as $100 per hour of on-line instruction (29:33). Other estimates based on purchasing a mainframe computer system, using it effectively, and amortizing costs over 10 years, came in as low as $4 per hour (29:33). Yet, even then educators and researchers felt the associated costs for CAI were economical. At that time, Kopstein said "I have studied the economics of CAI and find that on the basis of a per hour-per student cost of instruction, a favorable comparison is possible with conventional classroom instruction" (29:33).

Today, a personal computer with the power of a $10,000,000 machine of 30 years ago can be bought for under $1000 (4, 51). In light of the increasing capabilities and decreasing costs of today's computers, one could conclude the economics of CAI should always be favorable. Lewis et al. detailed conditions under which they believe CAI can be cost effective. Those conditions are when

> (a) [CAI] costs the same as conventional instruction but contributes more to student achievement in the same amount of instructional time, or (b) it costs less or results in less training/instructional time for students to achieve the same learning outcomes as conventional instruction and/or (c) it results in an increase in student-teacher ratios (which can be translated into lower overall costs to the system) [52:93].

Rose agrees with this last point when he states that with CAI "student to instructor ratios could be doubled, as a conservative estimate, without sacrificing the quality of instruction" (67:8).

However, some researchers disagree with this conclusion. In 1982, Shavelson and Winkler stated that most cost effectiveness studies done up to that point had been flawed. Specifically, they noted three categories of gross assumptions made in many studies. These they called assumptions about the hardware and software components of the computer system (such as overestimating system capabilities), assumptions about the rate of use of the system (overestimating use), and assumptions about the life span of the system (overestimating life span) (71:3). They warned that too many studies focused only on the hardware cost of a CAI system and not on the personnel, maintenence, and operating costs. Indeed, they cited research that indicated that only 28 percent of the total annualized costs are hardware related (71:4). Consequently, CAI cost effectiveness reports should be reviewed carefully with the above possible flaws in mind.

This researcher could find few detailed cost analyses in the literature. Some researchers would simply equate CAI use with cost effectiveness. One study, which reported much of the costs associated with the study, concluded "The results of this initial study demonstrated that the system was utilized, making it a cost-effective curriculum tool" (42:45). Clearly, a system that is not used cannot be cost effective; however, just because a system is used does not guarantee it is cost-effective. Indeed, the cost per hour of student instruction at the end of the study was approximately $4.20 (rental cost divided by number of hours used) (42:45), a figure which some would consider too high.

The conclusion of another study report was similarly flawed. This report made no mention of costs until the conclusion which contained the statement "since students in the computer group attained even higher levels of mastery of the content, these CAI modules were certainly economically advantageous to faculty.. . . They were also time- and cost-efficient" (72:66).

Another consideration in performing cost analysis of CAI is presented by Schlechter. He reports study results that indicate that CAI time savings may be due to self-pacing, a characteristic of other less-expenive instructional methods such as programmed text (68:5). Indeed, little argument can be offered to refute that if a requirement can be met by programmed text that it should not be so done. The key feature of CAI is interactivity. If an instructional requirement demands interactivity then CAI, traditional classroom instruction, or another interactive method must be used.

Additionally, CAI cost effectiveness is not simply answering the question, "Can we afford it?" CAI must be compared to other methods that will fulfill the lesson requirements along cost effectiveness lines. Thus, the question the educational programmer must ask is more like the following, "Is CAI the most cost effective teaching method of those methods that will adequately do the job?" When doing this comparison, it is imperative that "all potential costs for [CAI] and the alternative medium must also be identified and examined" (68:11). Some of these potential costs include "associated documents (e.g., work-books), and furniture (e.g., carrels, tables, chairs) all [of which] need to be financed and procured" (46:32). Other considerations include facility modifications such as electrical hook-ups and air conditioning as well as human factors considerations such as room color and lighting (46:32-33).

The following general guide is provided by one group of researchers to assess the cost effectiveness of CAI:

1. Identify the costs of traditional instruction.
2. Identify separately the costs associated with the development, implementation, and operationalization of CAI instruction.
3. Measure the effectiveness of trainees in the field who are graduates of each mode of instruction.
4. Identify the costs of repairing any deficiencies associated with the current training methods.
5. Compare the two systems to determine if the investment in CAI is warrented (46:35-36).

Additionally, Schlechter advises that "Cost analysis must be done for each [CAI] implementation" (68:11). In other words, one cost analysis should not be used to justify a blanket adoption of CAI over other methods.

In summary, "research studies on the cost effectiveness of CAI have been inconclusive;. . . most decisions to implement CAI, therefore, are based on the consideration of [qualitative] benefits" (46:36-37).

Question 6

What hardware and software are necessary to build CAI lessons?

The tools required to build and present CAI lessons include both hardware (the physical equipment and components of a computer system) (13), and software (the programs and other instructions that govern the operation of a computer system) (13). Hardware considerations include a variety of factors such as the computer input device, memory size, color/monochrome display, and interactive video. Software considerations include the choice of the software language or program used to develop the lesson. These specific considerations will be addressed in more detail below.

CAI Development Tools-Hardware. In years past a large mainframe computer was necessary to provide CAI. However, today "multi-purpose microcomputer systems offer the ability to handle programming, CAE (Computer-Aided Engineering), CAI, and software development" (37:741).

Input Devices. Input devices are the tools used by the student to interact with the computer system and hence the educational program itself. Such devices include light pens, joy sticks, touch-screens, thumb-ball, computer mouse, and keyboard (11). Today's authoring systems "can accept and analyze screen positions entered with cursor keys, light pen, mouse, or touchscreen" (47). The literature does not contain a great deal of information about input devices. However, input option is a choice that must be compatible with the lesson design (39). A light pen alone may be a good choice for pointing out objects in a tutorial but not a good choice for short answer questions on a subsequent quiz. A touchscreen "allows direct hand/eye interaction and requires no additional desk space or other devices" (49:4). Unfortunately, some researchers report that a "touchscreen does not always detect 'touches'" (49:4). Army researchers found it necessary to provide audio confirmation for students by modifying the lesson program to produce a clicking sound after each touch input (49).

Some experts advise that multiple input means may be preferable (39). For instance, a fire-fighting simulation developed for the AFESC uses both a keyboard and a touch screen to accept input (40). In any case, the choice of input device(s) must be made dependant on the instructional objectives <u>and</u> upon projected future needs (39).

<u>Memory</u>. One consideration affecting hardware choice is the amount of available memory, commonly called random access memory or RAM, offered by the computer.

Simple CAI applications such as linear simulations require little memory (11). However, more involved applications such as "complex simulations demand more of everything" including memory (11:IV7, 39). Some authoring systems require a large amount of memory to develop lessons (640K for Maestro/PC), but much less to execute them (53). Thus the machine chosen to deliver lessons could have a smaller memory, an option which equates to less cost than the authoring machine's. An important consideration regarding memory is to consider present and future needs and have memory enough available for those needs (39). Some experts felt that in the future machine memory is not likely to be the stumbling block it was in the past. New technology such as the videodisc and compact disc are overcoming many past limitations (39).

Interactive Videodisc. An application of CAI receiving much attention these days is the combination of the computer and CAI software and the videodisc machine (6, 67, 75, 77). Interactive videodisc (IVD) permits the display of picture frames and video segments, and brings sound/voice into the CAI process. "The videodisc has a number of distinct advantages when used for interactive learning. It provides extremely high-density storage (54,000 indivdual frames per side), quick random access, and high replicability" (77:173). Rose said that IVD should be thought of as "a random access, variable speed film projector" (67:28). He further describes IVD's capabilities as similar to that of "a film projector capable of infinitely variable speeds from three times normal to still frames, [with] random access to any frame of a 30 minute movie in less than a second" and with capability of playing in reverse as well (67:32). The operation of the videodisc is as described below:

> Images are carried deep within a plastic disk in digital form and read by a low power laser beam. No contact is made on the rotating disk by a needle or film shuttle so the image will not be scraped off. It is almost silent in operation. The accessing of frames and all other functions of the player can be computer controlled on most industrial models. [67:33].

Verano, speaking for his collegues at the Air Force Academy, said the following of IVD with regard to IVD's capability to enhance language instruction:

> We feel that one of the most promising developments in approximating this interactivity and purposeful communication . . . is the microcomputer/videodisc combination. With this technology we can come remarkably close to simulating an actual German or French or Spanish speaking environment, creating a mini-world, as it were, for the student, allowing him or her to interact with the material being presented [77:172].

His feelings are echoed by DeBeers, who believes "videodisc optical technology is the wave of the future" (14:C10). Yet some, such as Gery, are not convinced that IVD will be any more effective than present CAI methods. She said IVD is "very expensive, very inflexible, and it adds another layer of complexity. If we don't understand interactivity yet, we don't need another layer of complexity" (30:C8).

Despite doubts such as these, "the use of video is exploding in many organizations" (6:27). As Bové says:

> the videodisc enables trainees to go through simulated exercises that would be difficult or dangerous to recreate realistically. And, the videodisc has proven effective in more mundane mechanical and technical training in which computer skills necessary for job functions are built into the program [6:27].

<u>Color</u>. The use of a color display in CAI would appear to be either a nice-to-have option or a necessity depending on which expert is consulted. Conkright states color aids in keeping the student's attention:

> [Color] holds his attention and holds it longer. This in turn greatly increases the chances that the learner will actually complete the program.. . . [H]aving completed a color program, the learner will more likely evaluate it as a good program and perhaps even tell [peers] about it. This of course completes the loop, helping to motivate others to get started [12:I66].

He goes on to cite a review of almost 30 studies about the use of color to provide improved learning and retention, conducted by Durrett and Stimmel, whose main conclusion was that "color should be used selectedly to draw attention to specific material" (12:I64). However, this study concluded with a warning that "too much color appears to be detrimental" (12:I64).

Rose believes "color is used effectively in most of the modern software to either differentiate entries or just to make the lessons less boring" (67:27). Conkright identified several key areas where the use of color may be a critical factor:

1. Where the subject content includes the skill of color discrimination, such as determining the meaning of a certain color code on wiring or the meaning of a colored warning light.

2. Where there is a need to put a lot of information on a computer monitor, thus necessitating the need for color so the student can discriminate between blocks of information. Here color can make it easier to understand any graphics in the lesson.

3. Where there will be three dimensional representations. "See-through drawings and complex surface contouring done in monochrome can be extremely difficult to interpret. Additional colors for each layer greatly assist the user."

4. Where there will be realistic simulations and animation. These amplify the need for color. "Color increases the fidelity or realism of nearly every simulation" (12:166-68).

Finally, Alessi and Trollip recommend the use of color to provide emphasis in tutorial CAI (4:83).

CAI Development Tools-Software Choices. Besides hardware, there are two other variables in the CAI lesson development process: who does the lesson development and what tool (software) they use. Briefly, the first variable is basically a choice from a range of people, starting with the subject-matter expert (SME) alone or working with a team consisting of the SME(s), measurement specialists, media specialists, programmers, CAI designers (46), and "even personnel outside the organization such as occupational survey specialists from the USAF Occupational Measurement Center" (17:1-5). Kemner-Richardson et al. outline four types of lesson development groups: "the inpired programmer-author, the traditional development team, the computer-supported development team, and the computer-guided author" (46:27-29). The SME can be an academic instructor or a recognized expert outside of academia. The CAI designer is an expert in course formulation for presentation via the computer.

The second variable is the choice between four types of software tools available for lesson development. Those software tools include higher order languages, authoring languages, authoring systems, and design systems (46:40).

Higher Order Languages. "A higher order language is a general-purpose computer language that can be used for a variety of applications, including the development of CAI courseware" (46:78). Higher order languages are the popular programming languages such as BASIC, COBOL, FORTRAN, and Pascal. Use of such languages has certain advantages and disadvantages.

On the plus side, higher order languages tend to be relatively inexpensive from the view of software costs. Many computers come with such languages included at no extra cost. A second advantage of such languages it that lessons developed using such languages tend to be easily transportable from one machine to another with little or no changes to the program code. For instance, a lesson written in Wang BASIC for a Wang computer system can be easily modified to run on BASIC on a Zenith system.

On the other hand, because such languages contain no commands specific to CAI, even the simplest of actions requires a great deal of programming code. A second disadvantage of higher order languages is that a great deal of programming experience and a great deal of time are necessary to develop even the most elementary of lessons. Thirdly, once developed, a CAI lesson will be very difficult to modify or update because of the size and complexity of the program. Finally, extensive training is required for the non-programmer (like the subject matter expert) to be able to use a higher order language independently of a programmer. Thus the use of a team approach to lesson development is virtually required.

Authoring Languages. An alternative to a higher order language is an authoring language. Kemner-Richardson et al. describe an authoring language as

> . . . a special-purpose computer language specific to the development of CAI. The command structure of an authoring language is specific to the instructional functions that are necessary to present text or graphics, accept student input, evaluate student input, and branch program control based on the input made [46:83].

There are many commercially available authoring languages, each developed for a specific piece of computer hardware. For example, PC/Pilot is available for the IBM Personal

Computer or its clones, and MacPilot is available for the Apple MacIntosh (65). As with higher order languages, authoring languages have their advantages and disadvantages.

Authoring languages have an advantage over higher order languages in that they offer additional commands that address functions unique to CAI. Some of the functions available in an authoring language may include sound generation, waiting for a specific time period to elapse, maintaining a student record on file, matching a student's answer against a file of acceptable answers, or branching or jumping to another destination in the lesson (65). Any of these functions could be executed by a simple command as opposed to the string of commands that would be necessary to execute a similar action by a higher order language. Thus the use of an authoring language results in an overall smaller program to present a given lesson. Moreover, a lesson developed using an authoring language is easier to modify or update because the program code is less complicated than that associated with higher order languages. Finally, authoring languages are usually designed to operate with and support a variety of external devices such as: mouse, touch screen, light pen, compact disc, and videodisc (65).

One disadvantage associated with an authoring language is the costs involved with its use. Such costs usually go beyond purchase price and can include complicated licensing arrangements based on the number of sites using the software or the number of lessons, and copies of these lessons, produced. A second disadvantage is the requirement for training or experience, by the lesson developer, with the language itself. Finally a lesson developed using an authoring language is usually machine-specific, meaning it will only operate on one specific type of computer (or any other computer the emulates that computer).

Authoring Systems. An authoring system is essentially a program that allows for the development of CAI lessons by the use of prompts, menus (may be graphically based using a series of icons and a computer mouse), and help sequences (46:88). Authoring systems produce a specially formatted database consisting of the blocks of lesson materials as well as quizzes, answers, remedial sections, and all instructions necessary to connect these blocks together as the lesson developer intended. Authoring systems are generally broken into two parts. The first, the authoring program, "leads the author through the creation of a lesson database." The second, the delivery program, takes "the creative database and conveys it as a lesson" (46:90) to the student. Authoring systems have their own advantages and disadvantages.

One advantage of an authoring system is its efficiency. Gordon Schleicher states "Authoring systems . . . have been shown to reduce the time needed to write a CAI lesson by up to 90 percent" (69:20) over other methods. A second advantage is ease of use. Authoring systems are menu driven, a fact which allows the lesson writer to simply pick a function from the menu to invoke an action or routine. A third advantage is the minimal training time necessary to master such systems. Kemper-Richardson et al. state that "the effective use of an authoring system can usually be gained in one week; whereas . . . as long as one year [is] needed for the effective use of an authoring language" (46:88).

One major disadvantage of authoring systems, like authoring language, is the associated costs. Front end costs for the program itself will be expensive, and licensing costs will add to this basic price. In some instances, these licensing costs can dwarf the actual program costs. A second disadvantage is the loss of flexibility to the lesson developer. Authoring systems require the writer to follow a predefined format and use the functions specified by the system, which may not be ideal to the lesson at hand. Finally, authoring systems are machine specific, like authoring languages. Thus a lesson developed on one type of computer will not run on another (78).

Design Systems. The last software choice available to the lesson developer is a design system. Design systems are an extension of authoring systems in that they "organize the content of a lesson, course, or curriculum on the basis of a learning model and/or instructional model appropriate [to] . . . an area of instruction (i.e. management training, electronics trouble shooting, mathematics, etc.)"

(46:92). Essentially, the lesson developer will have a series of systematic design processes to choose from (or the design system will be orientated to some specific subject) one of which is more appropriate for the subject.

The design system, then, has all the advantages and disadvantages of an authoring system, but has an added advantage of allowing the lesson developer to choose the lesson design process most appropriate to the subject.

Summary

This chapter presented answers to the second three investigative questions concerning the educational impact of CAI.

The answer to question four discussed the educational effectiveness of CAI from two standpoints, student achievement and instructional time, and presents studies which indicate that CAI results in improvements in both aspects over conventional instruction.

The answer to question five discussed the cost effectiveness of CAI. In general, it was shown that few good cost analyses of CAI have been performed. Moreover, some ideas relating to the method of performing better cost analyses were presented.

The answer to question six discussed the tools necessary to build CAI lessons. Both hardware and software considerations were presented.

V. Civil Engineering Applications

Overview

The purpose of this chapter is to present and examine issues relative to the application of CAI to Air Force Civil Engineering instructional requirements. Specifically, the researcher investigated how others have used CAI, how the decision to choose CAI as an instructional methodology could be modeled, and how the "Wang VS" computer compared to the "Z248" as a CAI authoring and delivery device. These are the final three investigative questions presented in the methodology.

Question 7

How has CAI been used by others to meet training and educational requirements similar to those of Air Force Civil Engineering?

CAI has been and is being used to provide instruction across a great many subject areas. From 1984 to 1985, *Electronic Learning* magazine reviewed and reported instructional software and applications for subjects such as social studies, writing, foreign languages, math and problem solving, general science, vocational educational, business education, and arts and music (50). Unfortunately for Civil Engineering, much of this software is geared to elementary and secondary school requirements. Besides the above applications, studies mentioned thus far in this thesis covered such widely divergent applications as police officer training (83) and foreign language instruction (44).

Civil Engineering Instructional Requirements. Before reviewing the literature it was necessary to define Civil Engineering instructional requirements. Current Civil Engineering instructional requirements are essentially broken into two broad categories: vocational-style technical training for the base-level craftsmen, technicians, and specialists of a BCE organization (38) and undergraduate to graduate level education for Civil Engineering officers, senior NCOs, and civilian managers (60). Civil Engineering training is oriented to fulfulling the day-to-day, peacetime requirements for real property maintenance. Civil Engineering education is oriented to keeping people current on today's technology, to prepare for tomorrow's challenges (60), and to provide skills not already obtained.

In the future, Civil Engineering instructional requirements are very likely to expand. The former Dean of the AFIT School of Civil Engineering and Services, Colonel Marshall Nay, advocates expanding the traditional range of Civil Engineering training and education to include expanded readiness training and education, and foreign language instruction (60).

In this section, training and education have been addressed separately. Applications of CAI that were similar to the above requirements have been reported. Readiness training, as Colonel Nay described, could include equipment familiarization for all Civil Engineering personnel including officers (60). Consequently, the traditional instructional requirements mentioned in the previous paragraph may undergo drastic expansion in scope. Thus, CAI applicability to some of these proposed requirements was considered.

Technical Training. According to researchers, CAI training applications at the technical level in the private sector did not appear to be extensive. For instance, Hata reported the results of a survey of engineering technology programs. He indicated that "seventy-five percent of the programs reported no use of CAI materials within the curriculum" (37:740). Hata also reported that of those within the electronic technical training field that do use CAI "the areas in which CAI is being used are basic electric circuits, digital logic, and electronic devices" (37:740).

Other reported vocational applications of CAI are to "identify parts, review safety rules, and learn operating procedures" (50:42). Some experts have created vocational CAI tutorials. Leiske mentions one tutorial whose subject concerned welding with an acetylene torch (50:42).

One promising method of using CAI to provide or assist in technical training is the use of a computer to simulate a piece of equipment. A similar application is the use of a computer to control a piece of equipment (testing equipment, for example) and present a variety of problem situations to the student. Stephenson reported on the success of this method of using a computer, CAI software, and an interface device to provide technical training on the use of sophisticated testing equipment (75). The computer can sense the equipment's settings, provide a simulated testing scenario, and directly critique student actions (75). "In such a CAI system, the individual instru-ments will act as talkers or listeners . . . but the controlling computer now has an added role to play, namely that of 'teacher'" (75:6-8).

Stephenson contends that the interface device between an instrument and a CAI computer gives the instrumentation instructor a "CAI capability of unlimited potential" (75:6). He further envisions:

> . . . an AI [Artificial Intelligence] system being used to teach a student how to use an instrument he or she has never seen before, by starting with general precautions and initial 'power-up' control settings, continuing through the functions of the various controls, and leading up to the subtleties of interpreting data from the instrument when used to observe the output from other components in the AI system or from a test circuit the student has built (75:8).

This method of instruction has potential application to Civil Engineering technicians who deal with instrumentation and equipment calibration. Consequently, this method is being investigated by the Air Force Civil Engineering and Services Center (38). If pilot studies underway indicate that this is a viable training method for Civil Engineering, then technical trades such as heating, refrigeration, controls and alarms, and power production, which have been initially identified by Civil Engineering Educational

Programmers, will have their training requirements reviewed for accomplishment by this method (38).

Air Force researchers have already demonstrated that students perform at least equally well on equipment simulators as on the actual equipment itself and in some regards students perform better (55). Massey found that students trained on an equipment simulator (for the 6883 test station) "tend to perform better on troubleshooting problems" (55:II177).

While the literature does not indicate a great deal of actual CAI training applications, training using CAI in the military has been fairly extentively explored by all service branches. The Army has used CAI to provide combat vehicle identification training (34). Moreover, the Army has tested, and found workable, the use of CAI to provide training in armor platoon tactics by way of simulation (49). They have also developed and tested a small arms weapon trainer which uses a light pen attached to a weapon to fire at computer generated targets. The Army expects to use this device to provide training on the M16A1 rifle, M203 grenade launcher, M72A2 light antitank weapon, and Mark 19 automatic grenade launcher (70).

The Air Force Engineering and Services Center (AFESC) is also exploring the use of CAI to meet training needs (38). Simulation CAI prototypes for firefighters are under development (35). One has already been developed and tested that is based on fighting a fire on a C141 aircraft. Reports indicate that the simulation is highly successful at training firefighters on the tactics necessary to combat C141 fires (40). AFESC educational programmers are in the process of developing a second simulation based on an F15 aircraft. Presently, they are also deciding what hardware to purchase and distribute to allow delivery of these lessons at individual bases (35).

Another application being explored by the AFESC relates to readiness training. Experts have developed a prototype rapid runway repair (RRR) training simulation for RRR team chiefs and crater chiefs. Their purpose is to provide the RRR chiefs with a better understanding of the RRR process and their role in it (66).

Moreover, AFESC programmers have hired a firm to develop a training lesson for heating systems specialists (38). This lesson is aimed at providing boiler troubleshooting training for the Air Force heating systems technician similar in style to the equipment simulators discussed earlier (38).

In summary, the vocational or technical level use of CAI does not appear to be well established. Few existing CAI applications have been reported in the literature that directly meet the requirements of Air Force Civil Engineering. However, there may be numerous potential applications, some of which are being presently explored by the AFESC and others. Current research, especially by the Department of Defense, may identify other potential applications.

Education. The educational uses of CAI are well discussed in the literature. Unfortunately, as mentioned earlier, many of these applications are at the primary and secondary educational levels. A review of a courseware catalog such as *Perscom's Educational and Home Software Catalog* illustrates the variety of educational microcomputer software available today and the proportion of it designed for the elementary and secondary level student (23).

However, not all CAI educational software is at the secondary level. The Air Force Academy uses CAI to assist in undergraduate level aptitude testing to allow proper placement of students at a level appropriate to their present knowledge (25). Enger et al. believe their "Fundamentals Testing Program, is by far [their] most ambitious and one of [their] most successful CAI efforts to date" (25:135). Other academy CAI applications include the use of graphical computer demonstrations in calculus to help students "get a better understanding of some basic concepts."

Rose's analysis of the suitability of CAI in the engineering curriculum at the Naval Post Graduate Institute, led him to state "undergraduate level courses reviewing the basic engineering disciplines are usually considered to be the best candidates for CAI introduction" (67:25). Much of the instruction given at the AFIT School of Civil Engineering and Services (SOCES) is equivalent to lower graduate/upper undergraduate level engineering or management instruction (60). These courses are specifically tailored to the skills needed by the Civil Engineering officer/manager in his/her specialty. Often these courses review the basic fundamentals of the academic area prior to actually introducing new material to the student. For instance, in the electrical engineering courses the first day is devoted to the review of electrical fundamentals (26). CAI is being considered by AFIT instructors as a means of providing review of subject fundamentals for a potential student at the home base before he or she gets to AFIT (26). This would reduce the time the student is on temporary duty at the educational institution (or permit more lesson material to be presented) and permit the instructor to concentrate on his/her presentation of the new subject material.

Another undergraduate level application of CAI is related to foreign language instruction. Johnson and Osguthorpe reported that CAI has been used as a method to provide foreign language instruction (44). CAI, in the language lab role, proved to be far superior to the typical language audio tape with regards to knowledge achievement and student attitude (44). Students could "physically" respond to foreign language commands by way of manipulation of figures on the computer monitor (44). Thus, given the command in German to "Pick up the book," a student could actually pick up the book (for instance, with a mouse) and maniputate it as instructed by the lesson. The Air Force Academy is also experimenting with CAI in the foreign language instruction area.

However, not all higher level educational CAI applications are limited to fundamentals reviews such as those mentioned above. Graduate level uses of CAI have been reported. Wharton wrote that the Harvard Law School has used CAI extensively to aid in legal case study analysis (81). Moreover, CAI was used to provide simulated legal situations and problems that students would solve (81). Additionally, Michail and Rovick used CAI in physiology instruction to "assist in the achievement of many of the goals of live animal experiment" by way of simulations of cardiovascular and mechanical muscle response (58:24).

In summary, while the potential educational applications of CAI appear to be extensive, little existing software is available to meet Civil Engineering educational requirements. However, many parallel applications have been noted, such as fundamentals review, case study analysis, and foreign language familiarization (if this becomes a Civil Engineering educational requirement).

Question 8

What is the step-by-step process by which a specific Civil Engineering lesson would be evaluated for CAI development?

Given the factors presented thus far in this document and the additional factors about to be introduced, an analysis of the decision process concerning the adoption of CAI as an instructional medium was conducted.

Assumptions. The approach used was to take a hypothetical Civil Engineering instructional requirement and analyze the decisions and actions that would be necessary in the evaluation process leading up to the decision to adopt or reject CAI as the means of lesson accomplishment. A starting assumption was that this hypothetical instructional requirement was a valid one that was beyond the scope of more informal instructional techniques such as on-the-job training (OJT). In other words, the analysis that would lead to the acceptance or rejection of a perceived instructional requirement as a genuine one has been completed. The result of this analysis is assumed to verify the requirement as a worthy one. The decision steps necessary to determine if a particular requirement is valid are covered in some detail in AFM 50-2, Instructional System Development (17); hence, they were not repeated here.

Additionally, this researcher assumed that the instructional requirements were all clearly identified prior to the start of the process of choosing the instructional methodology. Thus, the instructional goal, the instructional objectives, the target population, and that population's characteristics were all assumed to be known.

One final assumption made by this researcher must be introduced. This assumption was that quantitative and qualitative factors play an equal role in the decision process. In other words, rejection on the basis of costs was as final a rejection as that on the basis of qualitative considerations. In reality, qualitative considerations may be overriding. If CAI was the most "achievement effective" method for an important instruction requirement, then costs would, more than likely, play a less important role in the final decision of an instructional methodology. Mention of this possibility is made in the quantitative portion of the CAI adoption decision model (Figure 6).

A specific instructional requirement was used as an example in order to better lead the reader through the process. This requirement concerned heating systems repair specialist training for the heating AFSC (Air Force Specialty Code). This example was chosen because it was the subject matter picked by the AFESC for the prototype training program it is currently developing.

Media Selection Process. McConville concluded:

> Generally the internal steps of most media selection schemes are less visible ... This causes media [selection] decisions to be developed into a pool of acceptable choices where cost is the major determiner of the training system selected. A more educationally sound method is to combine the training efficiencies and cost efficiencies of the media selection model into a training measure of effectiveness that can be used to determine the best training system for the student learning situation [56:269].

Hence, the evaluation of CAI as an instructional method must involve considerations besides cost, such as population characteristics, alternate methods of instruction, hardware availability, software availability, organizational settings, and numerous other factors.

Stephens reviewed 25 CAI studies and identified 113 factors from these that were reported to affect the choice of CAI as an instructional methodology (74). He consolidated these and separated his resulting list of factors into three categories: efficiency, effectiveness, and practicality analysis factors (74:61-64). As depicted in his model, efficiency analysis primarily involved cost/benefit analysis, effectiveness involved factors related to courseware development and the net effect on learning, and practicality involved such factors as student attitudes, student population, and logistics considerations (74:58).

However, the distinctions Stephens presented appear to overlap. For instance, characteristics of the student population was a major factor in the cost analysis and in the practicality analysis. The analysis presented in this document will divide the factors into two broad categories, qualitative considerations and quantitative (or cost) considerations.

Qualitative Considerations. Qualitative analysis of CAI involves a look at the suitability of CAI to meet the instructional objectives. This researcher felt that qualitative analysis should come before quantitative analysis because there would be no reason to conduct the quantitative analysis if CAI was not an adequate instructional methodology. The reverse is not necessarily true. If CAI is not the most cost-effective methodology, then qualitative analysis would still be in order to determine if CAI would meet instruction objectives.

Qualitative analysis will include a review of the population's characteristics, consideration of the time constraints, consideration of resource constraints, and a review of the subject material to see if it is suitable for CAI delivery.

Population Characteristics. One qualitative issue involves the receptivity of the target population to CAI delivered instruction. Some people are less receptive to instruction via computer because of fears resulting from either unfamiliarity with computers or as a result of gender differences (63). With regard to the latter, Parker and Widner stated that "females were more likely then males to fear taking a computer course" (63:306). Moreover, "evidence is emerging to suggest that computers at the precollege level are being male dominated" (63:306). Jay calls this general fear of computers phenomenon, "computerphobia" (41), while others such as Schlechter call it "computer anxiety" (68). Before CAI can be adopted as an instructional method, the lesson developer must be able to answer the question "Is the target population one whose characteristics have been identified as being unreceptive to Computer Assisted Instruction?" A negative answer is important because people not receptive to CAI are less likely to learn than those who have no resistance to CAI. As Knapper (as quoted by Clements) reported, "Students resistant to computer implemented instruction at the beginning of a course learn less than they would with traditional instructional methods" (10:28).

Focusing on the example population of heating systems technicians, one could conclude that there would be little resistance to CAI because of gender. Virtually all heating technicians are male (a 1 September 1987 poll of the Heat Shop and Heat Plants at Wright-Patterson AFB indicated that of 190 personnel, none were female). Moreover, these craftsmen deal with electronic testing equipment, are mechanically inclined, and have been exposed to today's heating systems controls and technology which is largely microprocessor based. In summary, one would expect little overall resistance from heating technicians toward CAI as an instructional methodology.

Time Constraints. As reported earlier, Moyer states that "Technical problems in presenting information [may] make it impractical to be presented by the computer" (59:12). One of these problems includes time (59). Two kinds of time constraints can come into play. First, there may be a limited amount of time on the part of an expert or group of experts to develop a CAI lesson. The amount of time to develop a CAI instructional lesson can range from 25 to 300 hours per contact hour of lesson (46). Second, there may be insufficient time between the identification of the instructional requirement and the time the instruction is required by the population. For, instance, the identification of a safety-related problem may require that immediate instruction be given to all those concerned to prevent an accident or injury.

Thus, the question "Can the instructional requirement wait the time required to prepare a CAI lesson?" must be answered favorably. With regards to heating systems training the answer would be favorable. The kind of training proposed is general instruction meant to review the scope of knowledge the heating technician already possesses and as such is not time critical.

Resource Constraints. Other constraints could impact the decision to adopt CAI as an instructional methodology. Besides time, Moyer identified equipment as a constraint (59:12). Kemner-Richardson et al. identify "Hardware, software, . . . , physical and human factors, and personnel" (46:31) as resource factors in the CAI adoption decision. These factors can operate as constraints.

Hardware resource considerations revolve around the use of existing equipment or the lease or purchase of new equipment (46:31). Hardware could act as a constraint if selection is limited for political or other reasons.

Hardware can also constrain the selection of software.

Since most authoring software is written for IBM compatible computers, non-IBM compatible computers will limit the choices available to the lesson developer. Specifically, if there exists little authoring software for a specific system then there is a greater likelihood that the software capabilities needed may not exist in the limited selection available, as is the case with the Wang VS system as discussed later in this chapter.

Another potential constraint on CAI adoption is the physical space available within which to build CAI study areas with supporting documents and furniture (46:32). "Changes to classroom facilities also have to be assessed (e.g., room size, carrel layout, instructor station), as well as a variety of human factors issues in classroom design (e.g., lighting, air quality, room color, other comfort factors)" (46:32-33). These considerations may act as constraints in some organizational settings. For instance, in a heat plant it may not be possible to provide good lighting, air quality, or reasonable noise level for optimum learning conditions.

The final resource constraint to be mentioned here is personnel. Specifically, the trained, experienced personnel needed to develop, revise, and maintain courseware may not be available within the organization. Moreover, personnel with the necessary experience may not exist or may be unavailable from outside the organization. Even if the organization has the needed experts, these experts may have their attention directed to higher priority workloads, especially given the extensive time required to develop CAI lessons.

In summary, the instructional programmer must be able to favorably answer the following question in order to pursue CAI as an instructional method, "Do the non-financial resources necessary to develop CAI lesson material exist within the organization or are they obtainable outside the organization?"

With regard to a heating systems CAI lesson, this question may not be an easy one to answer. While the hardware, software, and personnel constraints may be overcome with adequate financial resources, the physical and human factors may not be so easily overcome if instruction was to be given in the shop. For the purposes of this example, it was assumed that this question is answered favorably.

Instructional Suitability. Some subject material may not lend itself well to CAI delivery. West identified several factors and conditions that contraindicate the kind of individualized instruction that CAI is geared toward. These factors and conditions are those that:

1. Provide familiarity with dangerous or infrequent operating conditions that cannot be simulated.
2. Require a great deal of hands-on experience that cannot be simulated.
3. Require personnel to be trained to work

predominantly as part of an integrated team.

4. Provide a substantial degree of interpersonnel skills for adequate job or task performance.

5. Have a group-paced format that currently satisfies all administrative and instructional objectives (80:428).

Moyer agreed with points two and four. He felt that concepts that deal with interpersonal relationships, where discussion or exchange of views is essential, and where a "manipulative skill is being taught" "may not be appropriate to computer presentation" (59:12). With regards to this last point, Moyer states "The computer could illustrate the technique of laying bricks, but one must actually handle the bricks and mortar to learn the trade" (59:12).

Additionally, training that requires teamwork accomplishment, such as rapid runway repair (RRR) training, would not appear suited for CAI, which is individually oriented. However, that is not to say that some individualized tasks within RRR are not CAI presentable.

Relating this to heating repair specialist instruction, it would appear that the only questions that could arise, given the nature of the instructional requirement and the job environment, would concern points one and two above. However, as was presented earlier in this chapter, equipment and systems operation can be and have been simulated for instructional purposes (55, 75). Thus, this step of the overall CAI analysis would not appear to eliminate CAI as an instructional methodology for the heating systems training application.

Hence, the lesson developer must ask: Is this instructional requirement suited for individual self-paced interactive instruction? If the answer is no, then another method of providing instruction should be evaluated. If the answer is yes, then further analysis would be required.

A flow chart of the qualitative portion of the decision process just discussed is presented in Figure 5.

Quantitative (Cost) Considerations. As discussed in chapter four, CAI lessons tend to be costly because of enormous up-front development costs. These costs, together with the other costs associated with CAI, must be compared to costs associated with other methodologies to determine if CAI is the best alternate from a cost viewpoint (46:36). Some researchers suggest "that the most meaningful relationship for comparing [CAI] with other methods is the cost per student hour" (Orlansky and String as reported in 46:36). However, this relationship would not give credit to any instructional method with shortened instructional time over other instructional methods. This researcher suggests the use of per person costs for a given lesson. Thus, costs would be tied to the desired end product, an educated or trained individual, and not to the time it takes to produce this result. Time savings would affect costs favorably either by allowing more people to be trained or by reducing a worker's time away from the job.

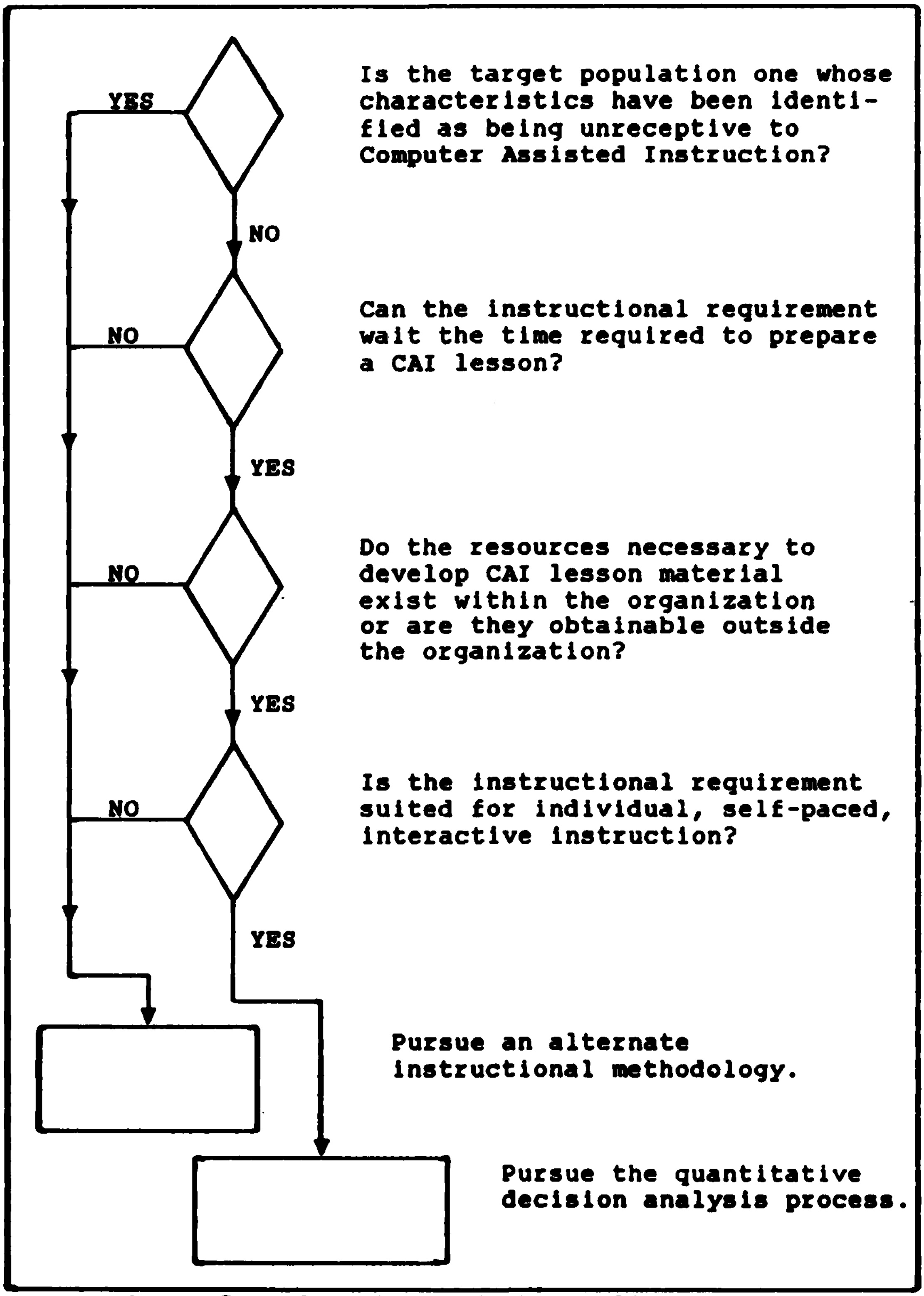

Figure 5. Flow Chart of the Qualitative Portion of the Decision Process to Adopt CAI as the Instructional Methodology

Net Population Size. To economically justify CAI as an instructional methodology, a CAI lesson must serve a net population large enough so that the per person costs are lower than costs for other instructional methodologies that could also meet the instructional objectives. A number of considerations impact the net population size: the total student population, the frequency of training requirement, and the turnover rate of the student population. As an example of the considerations involved in determining the net population size, consider that a new one-time instructional requirement would need to have costs spread over the existing student population in addition to any new members that join the population while the lesson is still valid. For instance, for the population of approximately 3000 heating specialists which receives about 200 new members every year (note that there is no need to consider outgoing personnel since their training is no longer the organization's responsibility) and which requires one-time instruction on some new topic or technique that will not be outdated for five years, the net population to divide the costs by would be 4000 (3000 initially trained plus 200 new members per year for five years). On the other hand, if this same population required this instruction on an annual basis, the net instructional population would be 15000 (3000 members x 5 years, assuming a stable population where incoming members equal outgoing members).

__CAI Costs__. The total cost associated with providing instruction using CAI includes the development costs, production costs, annual costs (maintainence, operations, etc.), and modification costs (68).

If the lesson is to be contractor developed, development costs may be estimated by consulting the appropriate contractor or by reviewing past contract costs for similar efforts. If the lesson is to be developed in-house, develoment costs must be estimated by summing estimates for the developer(s)' time, including hardware and software costs associated with developing the lesson (if more than one lesson is developed using the same hardware and software, these costs should be proportionally shared among the lessons), adding the cost of licenses associated with any commercial software used, and including the cost of travel, supplies, clerical support, and administrative overhead.

Production costs include costs associated with duplicating and distributing the lesson software and any associated printed material as well as the cost of the hardware and software associated with delivering the lesson (if more than one lesson is delivered using the same configuration, these costs should be proportionally shared).

Annual costs include operating costs such as utility charges for electricity and telecommunications, salaries for system operators or other CAI-related personnel, license fees for any commercial products used to deliver the lesson, supplies consumed in support of the lesson such as paper and ribbons, and hardware maintenance costs. The last item is often overlooked and, according to some experts, can be quite substantial (68).

Modification costs include most of the considerations of the development and production costs that relate to modification of the lesson. Thus, costs such as the salary of the developer(s), duplication and distribution expenses, and administrative overhead must be considered when estimating modification costs. Modifications may be planned at periodic points in the lesson's life to provide for technology changes, corrections, or upgrade.

Costs For Other Methodologies. Identifying CAI costs alone provides no basis for the instructional programmer to make a decision to accept or reject CAI on cost-effectiveness grounds. CAI costs must be compared to costs for other instructional methodologies that could meet the instructional objectives (46:35-36). Thus the costs for other instructional methods must be identified. Like CAI, these would include development costs such as experts' time to put together course material, annual costs such as instructors' salaries and students' salaries for the time in class.

With regard to the heating systems training such costs could include those just mentioned, and travel costs, per diem for TDY students, overtime for the unit from which the student came (to keep up with work schedules), and equipment trainers if applicable.

Figure 6. below illustrates the steps in the quantitative analysis.

The Total Model. The qualitative and quantitative portions of the decision process are really two pieces of what may be called the total model. This total model of the decision process to adopt CAI as an instructional methodology is presented in Figure 7.

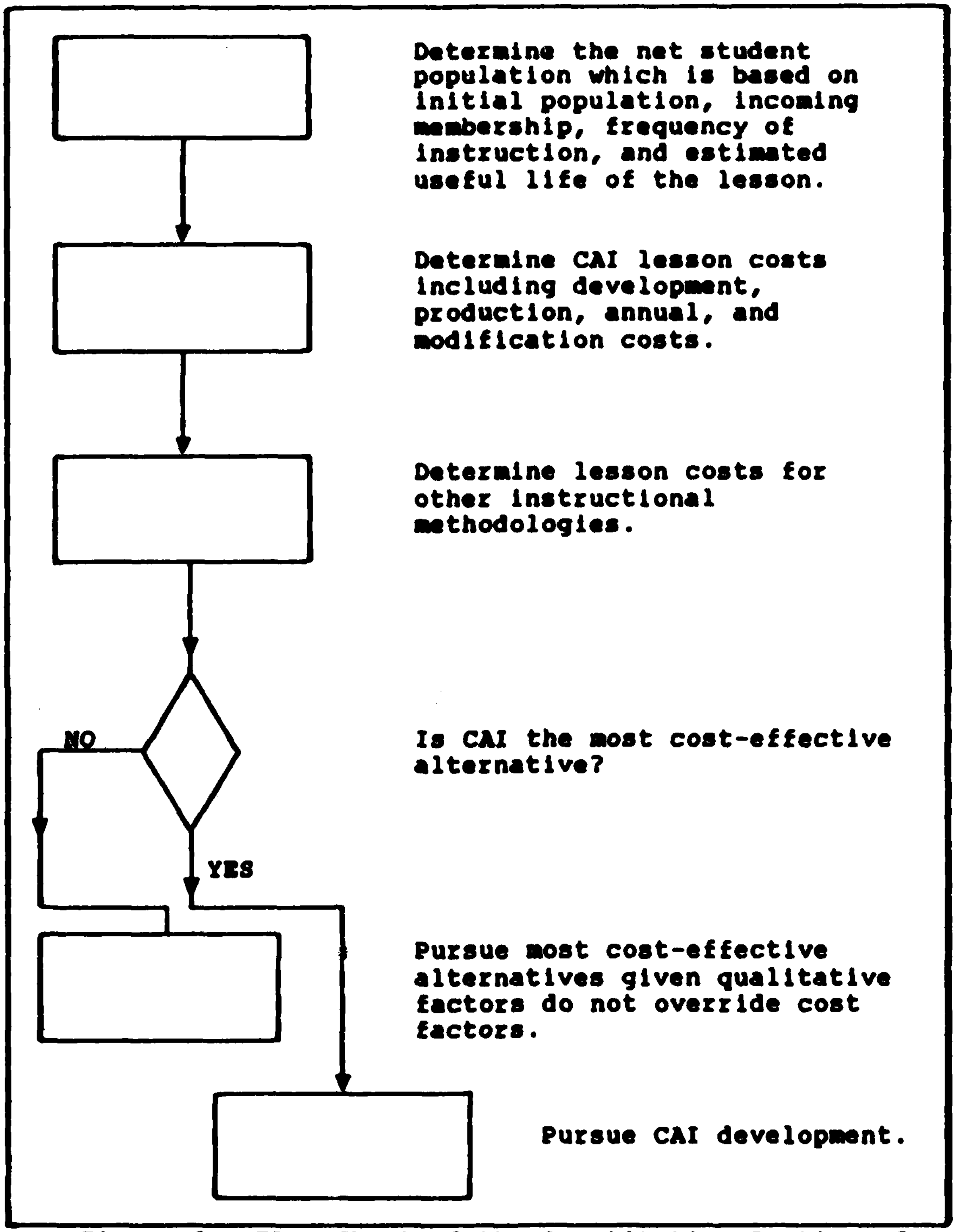

Figure 6. Flow Chart of the Quantitative Portion of the Decision Process to Adopt CAI as an Instructional Methodology.

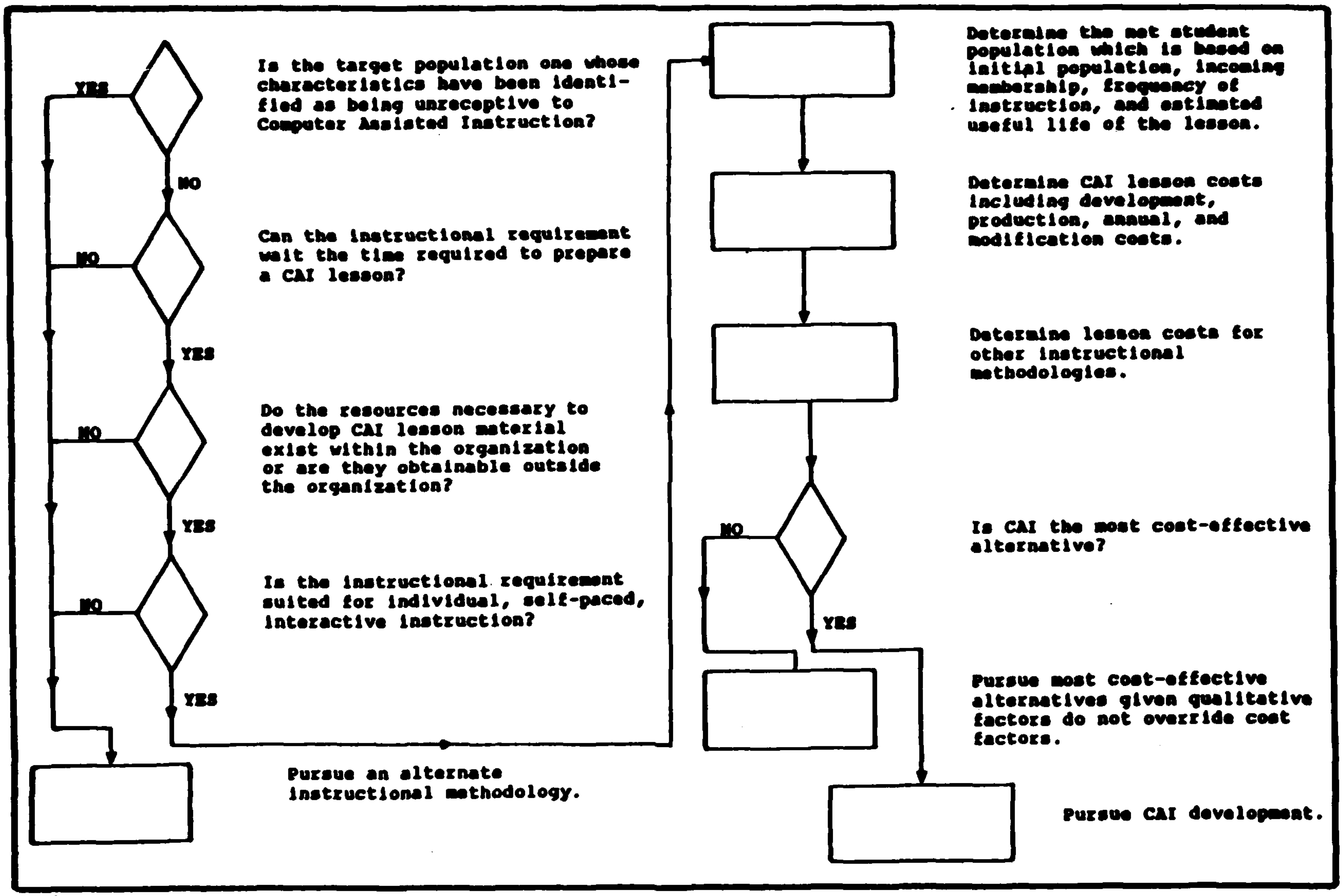

Figure 7. The Total Decision Process to Adopt CAI as the Instructional Methodology

Question 9

How does the 'Wang VS' computer system, being installed in Air Force Civil Engineering units as Work Information Management Systems (WIMS), in combination with the software available for it, compare as a CAI device to the Zenith Z248 computer and the software available for it?

Rose warns that "care should be taken to ensure that the software/hardware of the (authoring) package is compatable with any hardware that the (organization) already has or is locked into purchasing" (67:29). Given this advice, it would appear Air Force Civil Engineering should plan future CAI lessons/projects around the use of the 'Wang VS' system. This system has been or is in the process of being installed in every squadron-sized (or larger) Civil Engineering unit as a Work Information Management System (WIMS). However, Rose's words must not be accepted blindly without some evaluation. The following comparison examined costs and capabilities of the two systems from a software and hardware point of view. No recommendations are included herein.

Software Availability. The only authoring system available for the Wang VS computers at the time of the writing of this document was "VS Author" from Mentor Resources (78). On the other hand, the "Z248", being an IBM compatible, has a wide assortment of commercially available authoring software. Such authoring software includes

"Maestro/PC" (53), "PC/Pilot" (31), "CAI Plus" (31), and "INSIGHT" (82). This writer chose to compare "VS Author" to "Maestro/PC". This choice was, in part, arbitrarily made and, in part, based on the fact the writer has viewed the use of Maestro/PC and the writer was able to obtain product information. No endorsement is implied by this choice.

Table one summarizes the differences between the two systems.

Table I. Software Comparison Between VS Author and Maestro/PC (53, 78)

Software Comparison

	VS Author versus	Maestro/PC
Purchase Cost (single)	$12,800 *	$799 **
Delivery License Cost	Yes, unknown amount	NO
Graphics Capable	Only using VS character set	YES
Color Capable	NO	YES
Interactive Videodisc Capable	NO	YES
Ease of Use	Menu driven	Icon/mouse driven
Input Options	Keyboard	Mouse/Touch Screen/ Joy Stick/Trackball Lightpen

* As of 1 December 1986
** As of 1 June 1987/Price is less for educational institutions

Hardware Choices. The Wang VS system as purchased under the AMMUS contract consists of a number of workstations and microcomputers which serve as workstations tied into a central processing system. The alternative hardware configurations available to use the Wang VS system as a CAI device are (1) to use the system as presently configured, (2) alter or modify the existing system or a number of the microcomputers serving as workstations into CAI capable devices, or (3) purchase a new series of Wang IBM compatible microcomputers (5).

Each of these alternatives has its own advantages and disadvantages. Alternative one requires no hardware modifications but limits authoring to the use of the "VS Author" authoring system or a higher order language. As discussed earlier, the VS Author authoring system is very expensive, has no color capabilities, and has limited graphics capabilities. Also, as discussed in chapter four, higher order languages are not a good alternative because of the programming skills required and added time to develop lessons.

Alternative two would theoretically open the door to the use of IBM compatible authoring systems, but it is also an expensive option. Moreover, few software manufacturers will guarantee that their authoring systems would work on such machines.

Alternative three involves purchasing and using one of the new Wang IBM compatible micro computers (models 280 and

380) released in 1987 (79). These new Wang systems would run IBM authoring software and would also be able to serve as a VS terminal (79). However, the cost for this alternative is also high (see Table II).

These three Wang alternatives are compared to the Zenith "Z248." The "Z248" is an IBM compatible microcomputer under a DOD purchase contract (15). Appendix B lists hardware and software available under this contract. The Air Force Academy has used the "Z248" to present instruction by means of interactive videodisc using a Sony LDP-2000 series videodisc player controlled through an RS232 interface (32:21).

Table two summarizes the comparison. The cost cited in Table 2 for the Wang "Model 380" is retail price. Government contract price would probably be less. In any event, it would appear that the "Z248" may be the best choice if cost alone is the determining factor. However, if compatibility with the WIMS system is an overriding consideration, it would appear that the "Model 380" could prevail.

Table II. Hardware Comparison Between "Wang VS" and "Z248" (5, 45, 79)

Point of Comparison	Present Wang VS System	Modified Wang VS System	Wang Model 380	Zenith Z248 System
Cost *	---	$7079 #	$7695	$2263 #
Color capable	No	No	Yes	Yes
IVD capable	No	No	Yes	Yes
Other input options	No	No	Yes	Yes
(Input mouse)	No	Yes	Yes	Yes
Software capabilites	VS	VS IBM	IBM MS-DOS VS	IBM MS-DOS
VS system capable	Yes	Yes	Yes	No

*Costs based on RAM expansion to 640K, 20MB Hard Disk, high resolution color monitor, graphics card, mouse, and math coprocessor

#Government Contract Costs

Summary

This review of current literature on the subject of computer-assisted instruction (CAI) provided answers to the three investigative questions related to the specific application of CAI for Air Force Civil Engineering.

AD-A187 915 COMPUTER-ASSISTED INSTRUCTION AND ITS APPLICATION TO AIR FORCE CIVIL ENGINEERING(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH CCHOOL OF SYST.. R A FRYER 2/2

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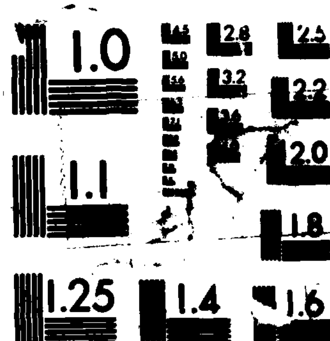

MICROCOPY RESOLUTION TEST CHART
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First, it was shown that there are few training and educational applications readily available to meet Civil Engineering instructional requirements but that several prototype applications are under investigation by the AFESC.

Next, a model of the CAI media selection decision was developed based on various considerations mentioned in the literature.

Finally, a comparison was made between the "Wang VS" and Zenith "Z248" computer systems as CAI devices and the authoring software available for each machine.

VI. Conclusions and Recommendations

Overview

This chapter summarizes the conclusions that could be drawn from a review of the literature relating to computer-assisted instruction. Recommendations for additional study are presented for those within Air Force Civil Engineering considering developing CAI instructional material.

Conclusions

After reviewing the literature, several conclusions were made regarding computer-assisted instruction.

First, the literature, when taken as a whole, indicated that computer-assisted instruction, as an instructional methodology, was a viable method of instruction under the right conditions. If designed properly, CAI was at least as effective as, and possibly more effective than, other methods from a student achievement point of view. When looking at the length of time it takes to instruct a student on a given subject, the literature indicated that CAI results in drastically reduced instructional time. However, this may be a result of the self-paced nature of CAI rather than any other feature of CAI, such as interactivity.

Second, the literature was woefully deficient of information on the cost effectiveness of CAI. Indications were that costs of CAI are frequently computed based on hardware and software costs alone. Moreover, it appeared that those responsible for lesson development are not making comparisons between CAI and other instructional methodologies that could satisfy the educational requirement. In fact, it appeared to this researcher that cost was simply a matter of staying under the allotted budget rather than using funds efficiently.

Third, the literature indicates that CAI lessons can be developed a number of ways using the programming avenues available to normal computer programming, such as higher order programming languages like BASIC or Pascal, or by specialized authoring software such as authoring languages or authoring systems. This authoring software is specially designed to ease CAI lesson development. Authoring software includes commands specific to CAI which perform such functions as branching, quizzing, and controlling external devices such as interactive videodisc.

Fourth, the literature indicates that a number of factors impact the choice of hardware and software tools used by the instructor to develop CAI lessons. The most important factors are the lesson objectives and future needs of the instructor and student.

Finally, the literature indicates that few presently available applications exist which meet Civil Engineering instructional requirements. Areas in which CAI has been used successfully to meet requirements similar to those of

Civil Engineering's include engineering fundamentals review and technical equipment training.

Recommendations

The following recommendations are offered for consideration by the Air Force Civil Engineering community in those efforts related to computer-assisted instruction:

1. Carefully test and evaluate the impact of introducing CAI to the base level Civil Engineering community, first, from a qualitative perspective and, then, from a total long-term cost perspective.
2. Maintain detailed records of all costs associated with future CAI lesson development projects. Conduct a careful and complete cost analysis and consider publishing the results to increase the database available to researchers studying this issue.
3. Consider new, unproven CAI applications after following the instructional systems development process. The general model included herein may prove a useful guide for considerations which are CAI unique.
4. Pursue the aggressive development of CAI delivered engineering fundamentals review for AFIT School of Civil Engineering and Services courses.
5. Consider developing CAI exportable training and education to meet a number of instructional requirements, such as that similar to continuing education.
6. Strive to develop a hardware and software standard

CAI system for Civil Engineering. This will provide some standardization with regard to hardware purchasing and maintenance, and courseware development.

Summary

Despite the fact that it is less than 25 years old, computer-assisted instruction has been shown to be a viable instructional method for certain applications. CAI possibilities have rapidly increased along with computer technology. CAI has applications to Air Force Civil Engineering instructional requirements and should be carefully evaluated as one means of meeting those requirements.

Appendix A: Glossary of Terms

Artificial intelligence - an area of study of computer science concerned with the development of a computer system capable of imitating the human thought process.

BASIC - An acronym for Begineers All Purpose Symbolic Instruction Code, a product of Kemeny and Kurtz of Dartmouth College (1963). BASIC "uses simple English words and common mathematical symbols to perform the necessary arithmetic and logical operations to solve problems" (22:56).

CAI - Computer-Assisted Instruction (or Computer-Aided Instruction).

COBOL - an acronym for COmmon Business Oriented Language, a high level programming language.

Courseware - a generic term for all types of CAI materials (46:32).

FORTRAN - an acronym for FORmula TRANslation, a higher level programming language.

Hard disk - a disk or series of disks made of a rigid base coated with a magnetic material which can typically store between 10 and 60 million bytes of information per device.

Hardware - the physical components of a computer system.

IVD - Interactive Videodisc.

Joy stick - a device connected to a computer which control the location of a cursor by the manipulate of a control lever which can be tilted in various directions.

K - represents 1024 bytes (2^10) of memory.

Keyboard - an arrangement of keys like those on a typewriter, used to enter data into a computer.

Light pen - a hand-held stylus connected by a cable to a some monitors, that can sense the light from the pen on the screen and translate that into a signal to the computer.

Modem - a MOdulator-DEModulator device that converts digital output into analog output and vice-versa for use in transmitting information by phone lines.

Monitor - the screen of a cathode ray tube (CRT) used with a computer.

Mouse - a small hand held device connected to a computer and monitor used to enter commands: the mouse is moved on the surface of a table or the like to position a cursor on the screen next to a command the user wishes to invoke.

Pascal - a higher order programming language designed to support the concepts of structured programming.

RAM - random access memory, a type of computer memory that can be accessed without following a sequence of storage locations.

ROM - read only memory, computer memory with preset instructions that cannot be written over or altered.

Software - the programs used to control the operation of a computer.

TICCIT - an acronym for Time-Shared Interactive Computer Controlled Instructional Television - a product of MITRE Corporation and Brigham Young University - a CAI system which uses a standard color television to present lessons to students who respond through a keyboard, all of which is controlled by a minicomputer (4:48).

Touch screen - a special monitor screen which can sense a touch from a finger and translate that touch into instructions to the computer.

Track ball - a device consisting of a sphere mounted in a box that can be rotated with the palm or fingertips that is connected to a computer with which one can manipulate to location of a cursor on the screen.

Note, unless otherwise noted, the above definitions come from Webster's NewWorld Dictionary of Computer Terms (13).

Appendix B: Hardware and Software Available from the Zenith Data Systems Contract. (Contract #F19630-86-D-002) and GSA Sources

HARDWARE

ITEM DESCRIPTION	UNIT COST	NSN	CLIN #	ZDS MOD #
Basic System	$1103.00	7010-01-232-9362	0001	ZFX-248-50
Intermediate System	1534.00	7010-NCC-218183	0002	ZWX-248-52
Advanced System	1658.00	7010-01-232-9363	0003	ZWX-248-62
Memory Expansion 640KB	120.00	7035-NCC-218113	0004AA	Z-405-A
Memory Expansion 2MB	240.00	7035-NCC-218314	0004AB	Z-415
20 MB Hard Disk Drive	302.00	7025-01-232-7371	0006AA	Z-217-22
40 MB Hard Disk	699.00		0006AB	ZD-400
1.2 MB Floppy Disk Drive	124.00		0006AE	ZD-12
Dual Mode Printer (Drft/Ltr)	528.00	7025-01-232-9333	0007	AL-2000
Cut Sheet Feeder	207.00	7025-01-232-9208	0008AA	MPI-350-I
Diablo C150 Clr Grphcs Prntr	802.00	7025-NCC-218137	0009	AFP-28
Graphics Plotter	929.00	7025-01-233-0239	0010	WG-2300
RGB Color Monitor	302.00	7025-01-232-9323	0011	ZVM-1380
Monochrome Monitor	116.00	7025-01-232-9324	0012	ZVM-1470-G
Graphics Input Device	293.00	7025-01-232-7351	0013	SI-1201
Power Converter	55.00	7025-01-223-5376	0014AA	HCA-370
Surge Suppressor	30.00	7025-NCC-218311	0014AB	CA-10-A
Dial-up 300-2400 baud Modem	158.00	7025-01-234-4070	0015	CTS-2424
High Speed Tape Backup Sys	478.00	7025-01-234-0832	0016	Z-427-20
8MHZ 80287 Math Co-procssr	143.00	7035-NCC-218315	0017AA	Z-416
60MB Tape Backup Unit	827.00			ZD-60
256K Print Buffer	181.00			AL-2000-3
9600 Baud Modem	255.00			ZM-192
140MB Hard Disk	2125.00			ZD-1200

SOFTWARE

ITEM DESCRIPTION	UNIT COST	NSN	CLIN #	ZDS MOD #
MS GW-Basic Compiler	$46.00	7030-NCC-218165	0018	MS-5063-4
Microsoft COBOL Compiler	15.00	7030-01-231-9804	0019	MS-5063-3
Microsoft Macro Assembler	9.00	7030-NCC-218167	0020	MS-5063-21
Microsoft FORTRAN Compiler	13.00	7030-NCC-216164	0021	MS-5063-2
Microsoft Pascal Compiler	16.00	7030-NCC-218166	0022	MS-5063-5
C Compiler	100.00	7030-NCC-218155	0023	CI-5063-1
WordStar Professional	130.00	7610-01-233-1050	0024AA	MP-5063-13
Multimate	148.00	7030-NCC-218173	0024AB	SS-5063-1
dBase III	355.00	7030-NCC-218148	0025AA	AT-5063-3
Condor III ver. 2.11	72.00	7030-01-288-8021	0025AB	CD-5063-3
dBase II ver. 2.43	239.00	7030-NCC-218185	0025AC	AT-5065-1
Microstat Statistical Pkg.	75.00	7030-NCC-218157	0026	ES-5063-1

ITEM DESCRIPTION	UNIT COST	NSN	CLIN #	ZDS MOD #
SuperCalc 3 ver. 2.1	76.00	7030-NCC-218170	0027	SC-5063-4
Graftalk ver. 3.27	81.00	7030-NCC-218168	0028	RG-5065-1
CAD Key ver. 2.0	280.00	7030-NCC-218161	0029	MC-3163-1
Time Line w/tutorial	53.00	7030-NCC-218150	0030	BS-5063-1
Enable ver. 1.15	87.00	7030-NCC-218171	0031	SG-5063-1
CXI Connectware 3278/9	422.00	7030-NCC-218156	0032AA	CX-5063-1
3780 IBM Terminal Emulator	96.00	7030-01-231-9805	0032AB	PO-5063-2
Zstem-304 VT100 Emulator	33.00	7030-NCC_218160	0032AC	KE-5063-1
VIP 7700/7800 Emulator	156.00	7030-NCC-218479	0032AD	CC-5063-2
Sperry Compatibility by CHI	121.00	7025-NCC-218153	0032AF	CC-5063-1
Micro-Bridge Burr Compat.	136.00	7030-NCC-218163	0032AG	MB-5065-1
Z100 Emulator	175.00	7030-NCC-218175	0032AH	Z-419
CAI Intro to Microcmptrs	11.00	7030-NCC-218151	0035AA	CB-3163-36
CAI for SuperCalc 3	23.00	7030-01-234-8604	0035AB	AS-5063-8
CAI for Condor III	42.00	7030-NCC-218154	0035AC	CD-5063-5
CAI for Microstat	5.00	7030-NCC-218152	0035AD	CB-5063-22
CAI for Program Management	14.00	7030-NCC-218149	0035AE	BS-5063-1
CAI for dBase II	36.00	7030-NCC-218144	0035AF	AS-5063-5
CAI for dBase III	23.00	7030-NCC-218146	0035AG	AS-5063-7
CAI for Multimate	23.00	7030-NCC-218145	0035AH	AS-5063-6
CAI for Bus Graphics	6.00	7030-NCC_218169	0035AJ	RG-5063-3
CAI for Composition Graphics	73.00	7030-NCC-218162	0035AK	MC-3163-2
CAI for Windowing	7.00	7030-NCC-218172	0035AL	SG-5063-2
LOGI MOUSE	50.00	7035-NCC-222733	0038	LG-7
ADA Compiler	1815.00		0040AA	AY-4164-1

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This investigation reviewed literature from a variety of sources pertaining to computer-assisted instruction (CAI) for two purposes. The first purpose was to compile information about CAI into a single condensed source for use by Air Force Civil Engineering educational programmers and managers. The second purpose was to examine and present information pertinent to the application of CAI to Air Force Civil Engineering.

The first section introduced such subjects areas as CAI terminology, definitions, instructional methodology choice considerations, courseware development, CAI delivery mechanics, and CAI applications.

The next section covered what the literature indicates about the educational impact of CAI. The literature states that CAI results in student achievement at least equal to that of traditional instruction. Moreover, instructional time has been widely reported to be decreased by the use of CAI, although some experts feel this is mostly a result of the individualized instructional environment which CAI offers students. With regard to the cost effectiveness of CAI, the literature contains few good cost analyses from which conclusions can be drawn.

The final section covered the applications of CAI to Air Force Civil Engineering instructional requirements. Actual reported CAI applications similar to Civil Engineering instructional requirements were presented. Such applications include equipment simulators for training purposes and tutorials with drill and practice for engineering fundamentals review. Additionally, a model of the decision process to adopt CAI as an instructional methodology was formulated. This model provides, in a broad sense, a guide to determine if CAI is the best instructional method to meet given instructional requirements. Finally, a comparison was made of the hardware and software alternatives presently available to the Civil Engineering lesson developer or programmer.

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